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The Jurassic and Lower Cretaceous of Wadi Hajar, southern Yemen

MICHAEL K. HOWARTH & NOEL J. MORRIS
Department of Palaeontology, The Natural History Museum, Cromwell Road, London SW7 5BD

SYNOPSIS. Jurassic and Lower Cretaceous rocks in Wadi Hajar are about 600 m thick, and consist of the Kohlan (oldest), Shuqra, Madbi, Naifa (Billum and Kilya Members), Hajar (Arus and Mintaq Members) and Qishn Formations, of which the Hajar Formation and its two members and the two members of the Naifa Formation are newly proposed here. The arenaceous Kohlan Formation overlies the Precambrian and contains no fossils in Wadi Hajar, but is dated elsewhere as Lower and Middle Jurassic. The calcareous Shuqra Formation is Callovian in age and contains many brachiopods, bivalves and gastropods. The argillaceous Madbi Formation also contains many brachiopods and molluscs, and a few ammonites that date it as Oxfordian. The Naifa Formation, Billum Member is calcareous with occasional Upper Oxfordian to Upper Kimmeridgian ammonites; the Kilya Member is more marly and contains many Beckeri Zone (Upper Kimmeridgian) and Hybonotum Zone (Lower Tithonian) ammonites. After a disconformity representing the remainder of the Lower Tithonian, the Hajar Formation, Arus Member is calcareous and marly, with gypsum veining and microbialite boulders in the lower part, and contains many Upper Tithonian ammonites. The Mintaq Member is highly calcareous, and contains many top Tithonian to mid-Berriasian ammonites. After another disconformity missing out the Valanginian and Lower Hauterivian, the Qishn Formation consists of sandy limestones, from which an Upper Hauterivian ammonite was obtained, followed by the *Orbitolina* Limestone of Upper Barremian to Aptian age.

INTRODUCTION

From its mouth on the Gulf of Aden, 430 km ENE of Aden and 80 km SW of Mukalla, Wadi Hajar extends inland for approximately 120 km north-westwards (Fig. 1). In Jurassic times the area now occupied by the south-eastern part of Wadi Hajar was part of a relatively slowly subsiding shelf sea, compared to the more rapidly sinking Hajar Basin to the north-west and the Balhaf Basin to the south-west. In this area Jurassic and Lower Cretaceous rocks lie directly on basement metamorphic and igneous rocks of Precambrian age, and they are overlain by younger Cretaceous and Tertiary rocks. Because of its large areas of good outcrop and relative ease of access, Wadi Hajar has been the scene of much exploratory collecting in recent years by those seeking standard successions through the Jurassic and suites of macro- and microfossils, for use in age determinations of borehole successions in basinal areas that lack outcrops of Jurassic rocks. In May 1991 two specimens of an undescribed Berriasian species of *Spiticeras* from the Mintaq Salt Dome in the upper part of Wadi Hajar were submitted to one of us (MKH) for determination. It was immediately clear that these represented an ammonite fauna and an age that had not been described before from Yemen. We were able to visit Wadi Hajar in November 1991, when we obtained more than 100 specimens from this new and splendid Berriasian ammonite fauna at Mintaq. We also collected about 30 ammonites from a difficult-to-interpret section in eastern Jebel Billum, of Upper Tithonian age, and several Upper Oxfordian ammonites from a nearby locality just above the base of the Naifa Formation. The latter ammonites were from one of two faunas that had been sampled by previous investigators, and after determination by Drs L.F. Spath and W.J. Arkell, ought to have resulted in an Upper Oxfordian to Kimmeridgian age being given to the Naifa Formation. We located and redetermined these previous collections, and we were then sent for determination some beautifully preserved examples of the basal Tithonian ammonite *Katroliceras*, as well as some top Kimmeridgian ammonites. These led us to believe that there was a great deal more variety in the Wadi Hajar Kimmeridgian and Tithonian ammonites than had been described before, and that although the Mintaq Salt Dome and Jebel Billum/Naifa Cliff/Wadi Kilya rocks were of very similar appearance, they contained entirely different ammonite faunas of very different dates, ie. Berriasian, and Upper Oxfordian to basal Tithonian respectively.

A new tentative correlation was drawn up of these Upper Jurassic rocks from Mintaq to Wadi Arus, Jebel Billum, Naifa Cliff and Wadi Kilya, that fitted in with the collections that were then available to us. With this as a working hypothesis, we made another visit to Wadi Hajar in January 1994. This yielded splendid collections of ammonites from both existing and entirely new localities and ages, and showed that the working correlation was largely correct, requiring modification only in detail. With the 580 ammonites collected on this second visit, we now had over 800 ammonites from the Jurassic and Lower Cretaceous of Wadi Hajar, all from known levels, and representing 14 biostratigraphical horizons from the middle of the Callovian to the middle of the Berriasian, the majority being from the top zone of the Tethyan Kimmeridgian to the Berriasian. Fossils of many other groups were also collected, foremost amongst them being Callovian and Oxfordian brachiopods that are abundant in the Shuqra and Madbi Formations. Numerous bivalves and a few echinoids were obtained from the same two formations, but in the Naifa and Hajar Formations faunas other than ammonites are much rarer or absent.

The purpose of this paper is to describe the Jurassic and Lower Cretaceous of Wadi Hajar between the south-easternmost locality at Al Ma'abir and the Mintaq Salt Dome, 65 km to the north-west (Fig. 1). As such it takes in the river section at Naifa Cliff and the nearby section in Wadi Kilya, both at Al Ma'abir, which together make up the type section of the Naifa Formation; the various sections in the outcrop along the southern side of Jebel Billum, where all the Jurassic formations are developed; the splendid exposures in the cliffs on both east and west sides of Wadi Arus and the road gorge climbing out of that wadi to the south-east, where there are exposures from the top of the Billum Member upwards, including the type sections of the Hajar Formation; and the exposures of the Mintaq Member in the Mintaq Salt Dome, where the beds have been

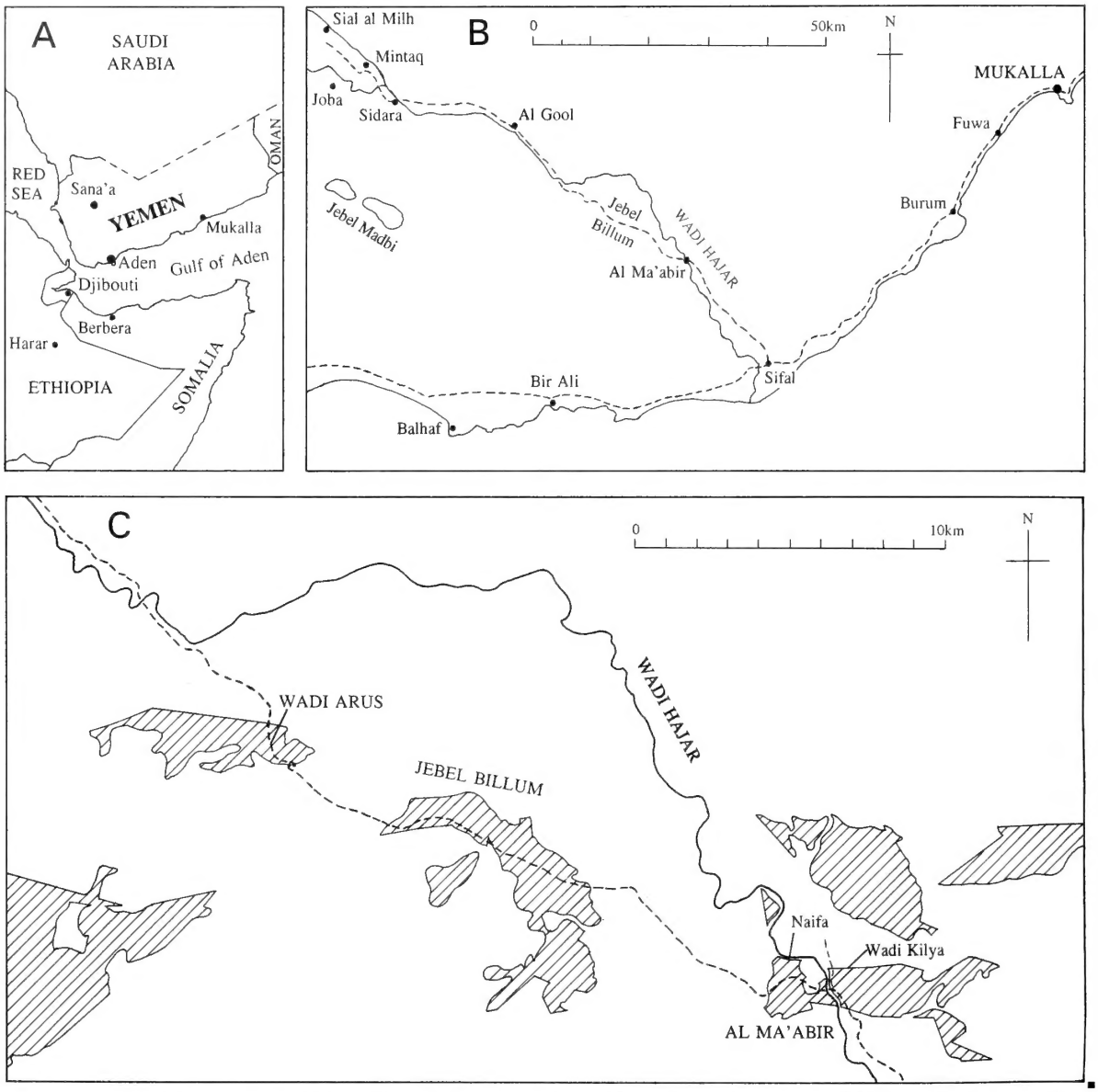


Fig. 1 **A**, location map of the southern part of the Arabian peninsula and north-east Africa. **B**, Wadi Hajar west of Mukalla extends from its mouth near Sifal to beyond the three salt domes of Mintaq, Joba and Sial al Milh, 90 km to the north-west. **C**, geological map of the lower part of Wadi Hajar from Al Ma'abir to Jebel Billum and Wadi Arus, showing the outcrop of Jurassic and basal Cretaceous rocks (hatched). The dashed lines on Figs 1B and 1C are roads.

pushed largely vertical by the rising core of the salt dome. The present paper, which deals with the lithostratigraphy and biostratigraphy, will be followed by papers describing the ammonites, brachiopods, echinoids and some of the bivalves.

PREVIOUS INVESTIGATIONS

Little, 1925

O.H. Little and H.M. Heald travelled up Wadi Hajar in February and March 1920 at the instigation of the Sultan of Shehr and Mukalla, mainly to investigate mineral deposits and agricultural methods. Accompanied by a retinue of 80–90 people, including 25 soldiers of the Sultan's private army for protection, they experienced great difficulty in passing through the formidable river gorge between Naifa and the mouth of Wadi Arus, at a time before the unmetalled road was constructed around the southern side of Jebel Billum. They penetrated Wadi Hajar as far as Jawl Bâhâwa (= Jol Ba Hawa; also the present Al Gool), but political and tribal reasons prevented them from going farther up the wadi to El Sidâra and thence to Mintaq. Nevertheless, Little made geological observations on the Jurassic outcrops at Naifa Cliff, Wadi Arus and near Hisn Bâqirdân (= Husn Ba Qirwan). The results were given in his paper (Little, 1925: 109–114). Three fragments of ammonites and three belemnites obtained from Naifa Cliff, and five bivalves and six brachiopods from Husn Ba Qirwan, were figured in the same paper by Stefanini (1925: 144–

208). Little (1925: pls 24, 26) drew vertical sections of the outcrop of the Naifa Formation in Naifa Cliff and in the east cliff in Wadi Arus, and suggested that oil shales of similar appearance in both sections were outcrops of the same bed. He was basically correct in making this correlation, though it is not now possible to interpret his more general section (Little, 1925: pl. 25) of the succession on the west side of Wadi Arus.

Beydoun, 1964

The exposures in Wadi Hajar formed a major part of Beydoun's (1964) description of the Jurassic over a much wider area in the south-eastern half of Yemen. This was based on field work by Z.R. Beydoun and E.K. Elliott in 1954–58, and resulted in the geological maps accompanying the published report (Beydoun, 1964: maps 1, 2) and the much more detailed unpublished reports held by British Petroleum Plc. Beydoun used four formation names for the Jurassic in Wadi Hajar – Kohlan Formation (oldest), Shuqra Formation, Madbi Formation, Naifa Formation (youngest) – though there are some difficulties in their interpetation because the type sections of the four formations are in widely separated parts of Yemen. Nevertheless, it is quite clear to which rocks Beydoun applied the formation names in Wadi Hajar, and our own work would not have been possible without the basic work done by Beydoun (1964: 30–46), in which he gave detailed lithological descriptions and long lists of fossils.

Lexique Stratigraphique International (Beydoun & Greenwood, 1968)

Formal definitions of the Kohlan, Shuqra, Madbi and Naifa Formations were given in the volume of the *Lexicon* that covered the southern Yemen area, from which it is clear that only the Naifa Formation has its type area in Wadi Hajar, though the type area of the Madbi Formation on nearby Jebel Madbi is only 20 km south-west of Wadi Hajar. On the other hand, the type area of the Shuqra Formation is at Shuqra, 80 km north-east of Aden, and 300 km south-west of Wadi Hajar, while the Kohlan Formation ought to have its type section in the Kohlan area north-west of Sana'a, though Beydoun (1968: 64) described his 'reference' section from its development at Al Ma'abir in Wadi Hajar.

Later mapping of the Wadi Hajar area

After the political changes in 1968–71, integrated geological mapping and exploration of southern Yemen was done in cooperation with geologists from three eastern European countries. The easternmost area extending as far as Mukalla was the province of geologists of the then German Democratic Republic, and this included maps for the area that contains Wadi Hajar. Maps were published in Aden by the Ministry of Energy and Minerals, Department of Geology and Mineral Exploration, of the then People's Democratic Republic of Yemen, on a scale of 1:100,000. The three sheets that have been used by us are D-39-49 (Jawl Ba Hawa), D-39-61/73 (Bir Ali/Balhaf) and D-39-62 (Mayfa Hajr), which we were able to consult through the kindness of BP Exploration. These maps have been of much value in locating the positions and extent of the sections we studied. They were prepared after some reconnaisance on the ground, followed by tracing geological boundaries and inserting detail from aerial photographs. The lithostratigraphical nomenclature used is largely that due to Beydoun, and some of the outcrops have to be interpreted with care, bearing in mind the errors and difficulties in his interpretation that are described below. One of these is the Madbi Formation on the Bir Ali/Balhaf map (D-39-61/73), from Jebel Madbi eastwards to the large area of outcrop around Jebel Timurah, which also includes the whole of the Naifa Formation as defined at its type locality at Naifa Cliff on the Mayfa Hajr map (D-39-62), where it is correctly mapped as Naifa Formation.

CORRELATION AND LITHOSTRATIGRAPHICAL NOMENCLATURE

On our first visit in November 1991, it became apparent that there was a significant unconformity within the 'Naifa Formation' in its outcrop at the eastern end of Jebel Billum. From beds above the unconformity some good Upper Tithonian ammonites were obtained, including some crushed top Tithonian berriasellids only 5 m below the base of the Qishn Formation (Upper Hauterivian-Barremian), which are much younger than the Upper Oxfordian to Upper Kimmeridgian ammonites that had been found lower in the Naifa Formation by Beydoun and other early collectors. The splendid new Berriasian ammonite fauna collected from the 'Naifa Formation' at Mintaq on the same visit was younger still.

Work in 1994 on all the sections (Al Ma'abir/Naifa Cliff/Wadi Kilya, Jebel Billum, Wadi Arus, Mintaq) led us to the conclusion that there are two different limestone formations in Wadi Hajar, separated by a series of marls, limestones and concretions, in the middle of which is a major unconformity or disconformity, where the whole of the Lower Tithonian is missing except for part of its basal zone (Fig. 2). Beydoun had correlated these two limestones, believing them to be separate outcrops of the same Naifa Formation, the consequences of which have had such a profound effect on all later work on the lithostratigraphy and biostratigraphy of the Jurassic in Yemen, that it is important to understand the origin of these errors.

The Naifa Formation is named from the development of limestones and marls at the type locality in Naifa Cliff, which is a river cliff about 2 km upstream from the road/river crossing at Al Ma'abir in Wadi Hajar. The top of the section at Naifa Cliff is overlain by recent river deposits, but at a nearby exposure in Wadi Kilya the Naifa Formation extends slightly higher into the base of the Lower Tithonian before being overlain by the Qishn Formation of Upper Hauterivian to Barremian age. Beydoun collected large perisphinctid ammonites from a horizon high in the Naifa Cliff section, which were determined by Dr W.J. Arkell as of Lower Kimmeridgian age. It is important to realise that Arkell was using 'Lower Kimmeridgian' in the north-western European sense, where it is equivalent to the whole of the Tethyan Kimmeridgian; this relationship is still valid today (ie. the Tethyan Kimmeridgian, divided into Lower Kimmeridgian and Upper Kimmeridgian, is equivalent to the Lower Kimmeridgian only of Britain), but this was not entirely clear in the mid-1950s when Arkell made these determinations, and the different north-western European and Tethyan divisions of the Kimmeridgian were not used consistently by Arkell (1956) in his *Jurassic Geology of the World*. Beydoun also collected some crushed ammonites from an horizon that is now known to be low in the sequence near Naifa Cliff, which were determined by Dr L.F. Spath as perisphinctids of top Oxfordian or basal Kimmeridgian age. Both sets of ammonites have been seen and redetermined by us, and there is no doubt that Arkell's and Spath's determinations and dating were basically correct (in fact, the higher Naifa Cliff ammonites are from the Beckeri Zone at the top of the Tethyan Upper Kimmeridgian, which is approximately equivalent to the top of the north-western European Lower Kimmeridgian). So the Naifa Formation at its type locality at Naifa Cliff extends from the top part of the Oxfordian up to the top of the (Tethyan) Kimmeridgian, and we now have further evidence

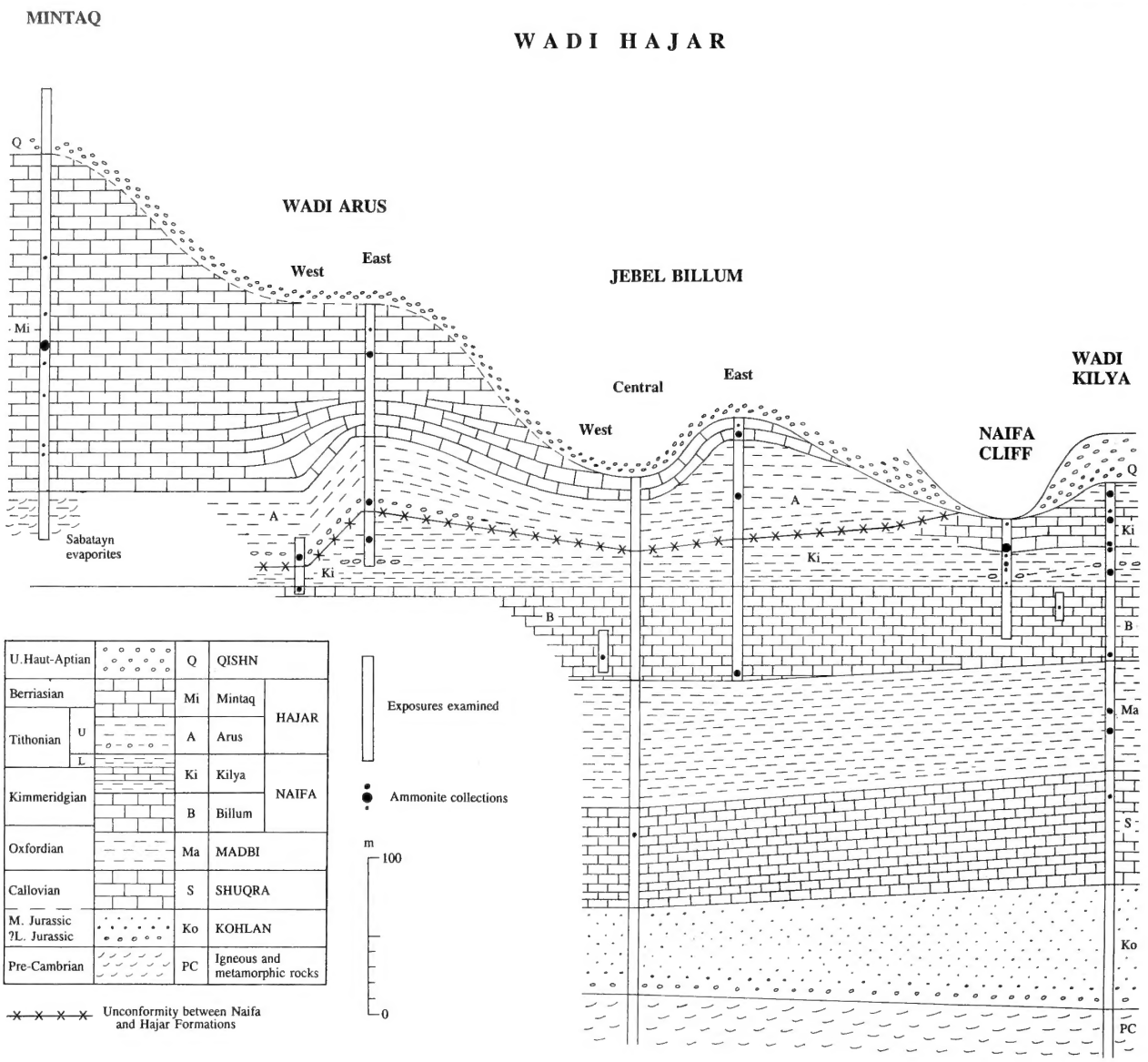


Fig. 2 Correlation of the Jurassic and basal Cretaceous formations in Wadi Hajar.

from Wadi Kilya, near Naifa Cliff, that the youngest beds extend into the basal zone of the Lower Tithonian.

Beydoun traced the Naifa Formation about 15 km north-westwards to the large Jurassic outcrop at Jebel Billum. Here it forms a very striking cliff along the south side of Jebel Billum. Ammonites found by us near the base of the formation near its eastern end, confirm that it is the same age as at Naifa Cliff (though it is truncated at the top by an unconformity, above which are Upper Tithonian marls and limestones of the Hajar Formation).

In Wadi Arus, 10 km north-west of Jebel Billum, there is a very prominent series of thick limestones and interbedded marls, especially well-exposed in the road gorge leading down into the upper end of Wadi Arus from the south-east, which Beydoun correlated with the Naifa Formation because of their great lithological similarity. He found a few poorly preserved ammonites in them, which were tentatively determined by Arkell as probably of Tithonian age. More important, however, was Beydoun's collection of some well-preserved ammonites from the marls and nodules (the 'Breadloaf Concretions') below the thick limestones, and from a few metres of limestone at the base, which are the lowest beds exposed in Wadi Arus. These ammonites were also determined by Arkell as Lower Kimmeridgian, and belong largely to the same species as found at Naifa Cliff. However, because Beydoun thought that the marls and Breadloaf Concretions were below the Naifa Formation, he identified them as the Madbi Formation and the basal few metres of limestone as the top of the Shuqra Formation. These lithological identifications were made despite the complete absence of brachiopods from these beds in Wadi Arus, in marked contrast to the immense numbers of well-preserved brachiopods that occur in the Madbi and Shuqra Formations in both Jebel Billum and the Naifa Cliff/Al Ma'abir area. This is the origin of Beydoun's (1964: 35, 36) records of ammonites from the Shuqra Formation (*Sutneria* aff.

galar (Oppel)) and the Madbi Formation (*Ataxioceras desmoides* Wegele, *Idoceras* cf. *farquharsoni* Spath, *Perisphinctes mombassanus* Dacqué, *P. (Pachysphinctes) robustus* Spath, *P. (Divisosphinctes)* cf. *inaequalis* Spath). In fact, none of these Kimmeridgian ammonites occur in the Shuqra and Madbi Formations, which are of entirely older dates: the basal limestone in Wadi Arus is the top of the Billum Member of the Naifa Formation, and the overlying marls and nodules (the Breadloaf Concretions) belong to the Kilya Member of the same formation and contain the same ammonites as at Naifa Cliff. This part of the succession in Wadi Arus ends at the same unconformity as found at Jebel Billum, that misses out the whole of the Lower Tithonian except for part of the basal zone. It is overlain by more marls (some with gypsum veining), concretions and microbialites[1], containing a splendid ammonite fauna entirely new to Yemen, of basal Upper Tithonian age, then by the massive limestones and interbedded marls that are so obvious in the road gorge leading down into Wadi Arus. Both belong to a new formation (here named the Hajar Formation); the upper massive limestones are largely poor in ammonites here, though a bed full of a new species of Upper Tithonian or basal Berriasian *Substeueroceras* was found in the upper half of the unit.

Another section that is crucial to an understanding of Beydoun's dating of the 'Naifa Formation' is in the Mintaq salt dome. As in Wadi Arus, there are thick massive limestones and interbedded marls in the Mintaq section that were identified as Naifa Formation by Beydoun, though here they are underlain not by marls and concretions, but by evaporites of the Sabatayn Formation. Many microfossils (foraminifera and calpionelids) were obtained from Beydoun's samples from the limestones of the Mintaq section, and they were dated as Upper Tithonian.

For the age of the rocks in Wadi Hajar that he referred to his Naifa Formation, Beydoun now had two incompatible dates: top Oxfordian to Kimmeridgian from the ammonites at Naifa Cliff and Jebel Billum, or Upper Tithonian from the microfossils at Mintaq and the meagre evidence in Wadi Arus. He chose the Upper Tithonian date from the Mintaq evidence. This was unfortunate, because the limestones at Mintaq and the upper limestones at Wadi Arus are not the same as those at Naifa Cliff/Al Ma'abir and Jebel Billum, and Upper Tithonian is a whole stage too high for the date of the Naifa Formation at its type locality in Naifa Cliff.

One final section to be considered is that at Jebel Madbi. Though we have not seen it ourselves, from Beydoun's detailed section and from subsequent photographs, it can be interpreted according to the nomenclature used by Beydoun himself at Naifa Cliff and Jebel Billum. The position of the base of the marly Madbi Formation is clear in Jebel Madbi, and this is its type locality. After a thickness of 100 m of marls, there are 74 m of limestones, then 78 m of more marly limestones, before a return to massive limestones, conglomeratic at the base, which attain the very large thickness of 434 m in Jebel Madbi. Because of the prominence of the latter limestones with conglomerates at their base, Beydoun identified them as the Naifa Formation, which made his underlying Madbi Formation 252 m thick, including the 74 m thick sequence of limestones in the middle. In fact, the latter limestones on Jebel Madbi are the lower half of the Naifa Formation (the Billum Member), the next 78 m of more marly limestones are the upper half the of same formation (the Kilya Member, exactly as at Naifa Cliff and in Wadi Kilya), and the overlying 434 m of conglomerates and massive limestones are the Hajar Formation, with the conglomerates at the base marking the unconformity.

[1]Calcareous bodies formed by algae, bacteria and cyanobacteria; they include stromatolites, thrombolites and dendrolites.

Table 1 Comparison of the lithological nomenclature for the Jurassic and basal Cretaceous in Wadi Hajar as proposed by Beydoun in 1964–68 and as used subsequently. In the left hand column **N** shows the range of the limestones at the type locality of the Naifa Formation at Naifa Cliff and close vicinity, while **M** shows the range of the limestones in the Mintaq Salt Dome.

BEYDOUN 1964-68	SUBSEQUENT INTERPRETATIONS		THIS PAPER	
Formation	Formation	Member	Formation	Member
M — NAIFA — N	NAIFA		HAJAR	Mintaq
				Arus
	MADBI	U. Madbi Shales	NAIFA	Kilya
		Madbi Porcellanites		Billum
MADBI		L. Madbi Shales	MADBI	
SHUQRA	SHUQRA		SHUQRA	
KOHLAN	KOHLAN		KOHLAN	

Beydoun's incorrect correlation between Naifa Cliff/Jebel Billum and Wadi Arus/Mintaq/Jebel Madbi has had profound effects on all later work. From the obvious lithological divisions in a section like Jebel Madbi, the terms Lower Madbi Shales (for the whole of the real Madbi Formation), Madbi Porcellanites (for the Billum Member of the Naifa Formation), Upper Madbi Shales (for the Kilya Member of the Naifa Formation), and 'Naifa Formation' (for the Hajar Formation as proposed here) have become widely used in recent years (see Table 1). Thus the term 'Naifa Formation' has been transferred to rocks of Upper Tithonian and Berriasian age. This has been done despite the fact that as a consequence there is no such 'Naifa Formation' at its type locality at Naifa Cliff. If lithostratigraphical nomenclature is to be used in a meaningful and practical way, then notice has to be taken of priority of usage and the rocks that occur at type sections, because to contend that a formation does not occur at its type locality leads to unacceptable instability of nomenclature. So the Naifa Formation is used here as originally defined from the rocks that occur at its type locality at Naifa Cliff and the immediate vicinity. Also the base of the Madbi Formation is drawn where it was first proposed at the base of the argillaceous formation in Jebel Madbi; it is about 100 m thick and extends as far up as the base of the overlying limestones, which are the same as the limestones of the Naifa Formation as defined at Naifa Cliff. On Jebel Madbi the Naifa Formation consists of a lower half of about 74 m of limestones, and an upper half of about 78 m of more marly limestones, up to the unconformity overlain by conglomerates and limestones of the Hajar Formation.

In his original definition in the Naifa Cliff/Al Ma'abir area (which includes Wadi Kilya), Beydoun was quite clear that the Naifa Formation consists of a lower limestone half, overlain by a more marly upper half, which we now call the Billum and Kilya Members respectively. The Kilya Member is terminated by an obvious unconformity in Wadi Arus, where it is followed by the Hajar Formation, with marls, limestones and concretions at the base (here named the Arus Member), then by thick massive limestones above. The latter limestones are prominent and thick at Mintaq, where they are here named the Mintaq Member of the Hajar Formation. The whole succession appears to attain its thickest, and perhaps most complete, development on Jebel Madbi, which would repay careful investigation and ammonite collecting. Beydoun's interpretation of

Table 2 Ammonite zones of the Callovian to Berriasian Stages in the Tethyan Province, and dates of the formations in Wadi Hajar (zones in the Callovian and Oxfordian Stages are based on Arkell (1956), Mouterde & Enay (1971: 16–21) and Cariou & Hantzpergue (1997: 80, 84, 362), those in the Kimmeridgian to Berriasian Stages on Howarth (1992: 599–601)). The horizons of dateable ammonite faunas in Yemen are shown by asterisks (*).

STAGES		AMMONITE ZONES	MEMBERS	FORMATIONS
BERRIASIAN		*Fauriella boissieri* *Tirnovella occitanica* *Pseudosubplanites euxinus*	* Mintaq	HAJAR
TITHONIAN	U	*Durangites* *Micracanthoceras microcanthum*	* Arus	
	L	*Micracanthoceras ponti* *Semiformiceras fallauxi* *Semiformiceras semiforme* *Neochetoceras darwini* *Hybonoticeras hybonotum*	Disconformity/unconformity	
KIMMERIDGIAN	U	*Hybonoticeras beckeri* *Aulacostephanus eudoxus* *Aspidoceras acanthicum*	* Kilya	NAIFA
	L	*Crussoliceras divisum* *Ataxioceras hypselocyclum* *Sutneria platynota*	* Billum	
OXFORDIAN	U	*Subnebrodites planula* *Epipeltoceras bimammatum* *Dichotomoceras bifurcatum*		
	M	*Gregoryceras transversarium* *Perisphinctes plicatilis*		* MADBI
	L	*Cardioceras cordatum* *Quenstedtoceras mariae*		*
CALLOVIAN	U	*Quenstedtoceras lamberti* *Peltoceras athleta*		
	M	*Erymnoceras coronatum* *Reineckeia anceps*		* SHUQRA
	L	*Sigaloceras calloviense* *Proplanulites koenigi* *Macrocephalites herveyi*		
BATHONIAN				KOHLAN

the Jebel Madbi section, with the limestone sequence (the Billum Member) sandwiched between two marl sequences, led to the proposal of the term Timurah Member in the explanation of the Bir Ali/Balhaf map (D-39-61/73) for the development of this middle limestone (the Billum Member) in the area around Jebel Timurah and Wadi Timurah, approximately half way between Jebel Madbi and Jebel Billum. We have not seen the type section or a formal description of the Timurah Member, so we do not adopt this term in preference to Billum Member.

LOCALITIES IN WADI HAJAR

Fig. 1 shows the location of Wadi Hajar and the main geological sections examined in relation to Mukalla and the surrounding area in southern Yemen, and also a more detailed map of the area in Wadi Hajar between Al Ma'abir and Wadi Arus. The series of formations and members in the Jurassic and Lower Cretaceous of Wadi Hajar that are recognized here are shown in the right hand column of Table 1. Of these, the Hajar Formation and its two members, and the two members of the Naifa Formation, are newly proposed in this paper. A general distribution and correlation diagram for the Jurassic and

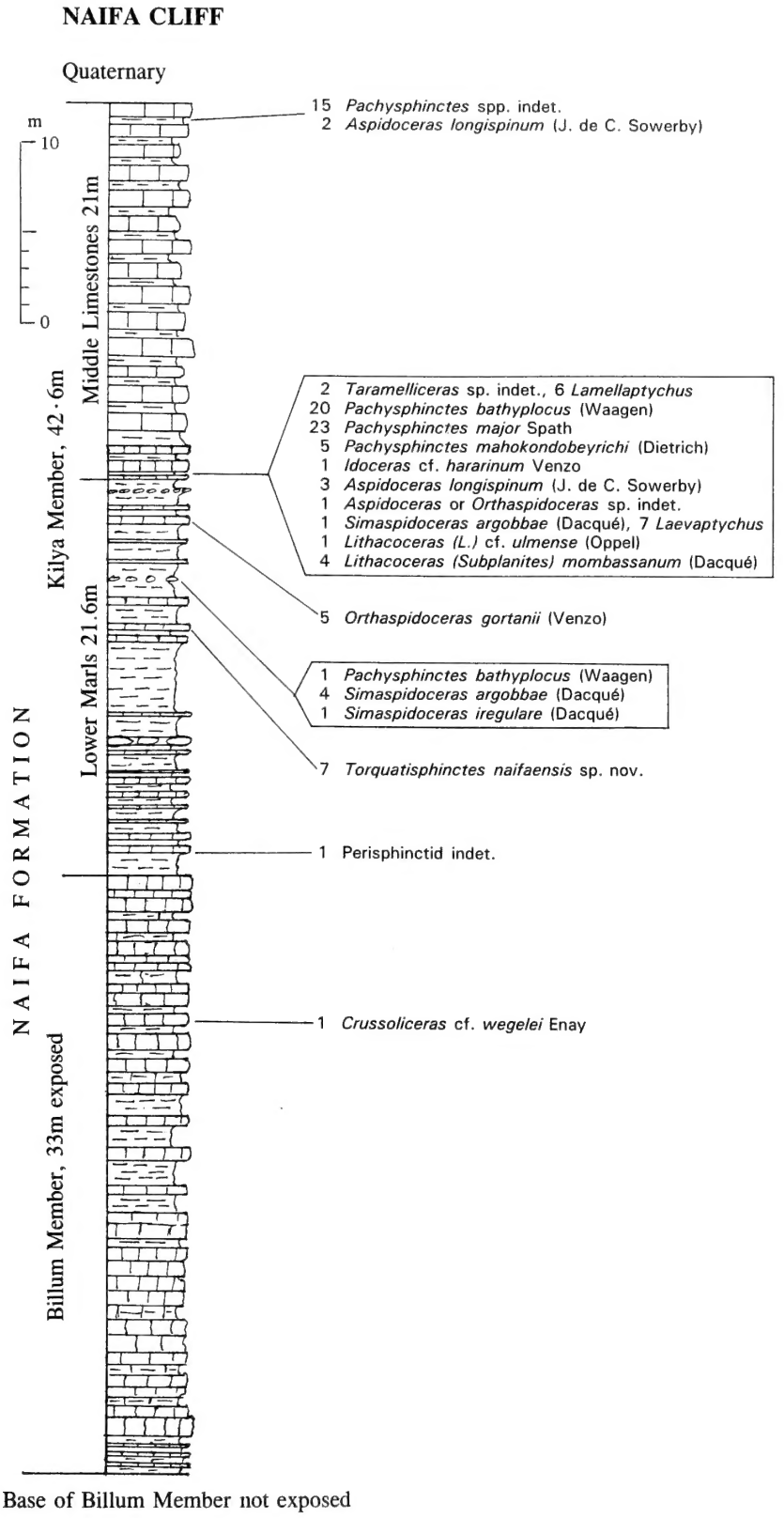


Fig. 3 Vertical section of the Naifa Formation at Naifa Cliff on the southern (right) bank of the river.

lowest Cretaceous in Wadi Hajar is given in Fig. 2, and a scheme of zones for the Callovian to Berriasian stages showing the positions of the dateable ammonite faunas in the Wadi Hajar succession, is given in Table 2.

Naifa Cliff

The splendid cliff section in the right bank of the river below the village of Naifa (=Neifa, Nayfa and Nayfah), approximately 2 km upstream from the road/river crossing at Al Ma'abir, is the type section of the Naifa Formation (see Fig. 9). The base of the Billum Member is not exposed in this cliff, but it is clear in the nearby locality south of Wadi Kilya (see below, and Fig. 5) and is also exposed immediately west of the road/river crossing at Al Ma'abir. In Naifa Cliff 33 m of alternating limestones and marly limestones of the Billum Member, in which no ammonites were found, are followed by the Kilya Member, which consists of 21.6 m of marls with subsidiary limestones in its lower part, then 21 m of thicker limestones in the upper part (Fig. 3). The upper marly part of the Kilya Member is missing at Naifa Cliff, where the highest horizon is near the top of the middle limestone part (as compared with the thicker development of the Kilya Member in Wadi Kilya), and the eroded top is overlain by Quaternary river gravels. The 'oil shales' of Little (1925: pl. 24) are probably at the base of the Kilya Member on Fig. 3. Considerable numbers of ammonites (mainly large perisphinctids) were found loose at the foot of the cliff, and they were traced to a mid-brown-weathering limestone near the bottom of the middle limestone part of the Kilya Member, as shown on Fig. 3. Some of the perisphinctids attain sizes larger than 250 mm diameter, and two exceptionally large (400–500 mm diameter) specimens of *Idoceras* cf. *hararinum* Venzo were seen, one of which was collected. Below this horizon of prolific ammonites, ammonites were collected from three other horizons. The upper one has body-chambers of *Orthaspidoceras gortani* (Venzo), the middle one has large examples of two species of *Simaspidoceras* preserved in grey limestone, while the lowest horizon has a new species of *Torquatisphinctes* (Fig. 3). The highest ammonites in Naifa Cliff are crushed specimens from a shell bed high in the middle limestones of the Kilya Member. All these ammonites belong to the Beckeri Zone of the (Tethyan) Upper Kimmeridgian. The single example of the Lower Kimmeridgian, Divisum Zone, ammonite *Crussoliceras* cf. *wegelei* Enay shown on Fig. 3 was collected from the upper part of the Billum Member in a nearby new road cutting, 0.5 km east of the road/river crossing at Al Ma'abir.

Wadi Kilya

This section through the Naifa Formation lies on the south side of the hill that is capped by the Qishn Formation on the south side of Wadi Kilya, 2.5 km E by S of Naifa Cliff (Fig. 4). The Kilya Member is thick and well-exposed here, being subdivided into three horizons. The lower marly horizon and the middle limestone horizon are both thicker than at Naifa Cliff, and are followed by a return to marls and thin limestones in an upper horizon (Fig. 5). The middle limestones contain many of the same perisphinctids and aspidoceratid ammonites as found in Naifa Cliff, while the lower marly horizon contains an horizon rich in crushed *Lithacoceras* and *Orthaspidoceras*. The section also extends to an upper marly horizon in the Kilya Member, which is at a higher horizon than the truncated top of Naifa Cliff. These upper marls are 15 m thick, and contain a bed with the best preserved ammonites in Wadi Hajar, especially *Katroliceras*, and species of *Hybonoticeras* that are distinctive of the Lower Tithonian, Hybonotum Zone. They are overlain unconformably by the Qishn Formation of Upper Hauterivian to Barremian age. To the south of the main section there is a long cliff exposure of the Billum Member, with a good basal contact with the shales of the Madbi Formation. The Billum Member limestones are 48 m thick here, and crushed *Orthosphinctes polygyratus* (Reinecke) and other ammonites distinctive of the Upper Oxfordian, Bimammatum Zone, were collected from the basal few metres.

The Kohlan, Shuqra and Madbi Formations were also examined in the area about 1 km south of Wadi Kilya and 1–1.5 km SE of the road/river crossing at Al Ma'abir. Detailed logs were made here of the Kohlan and lower and middle parts of the Shuqra Formations,

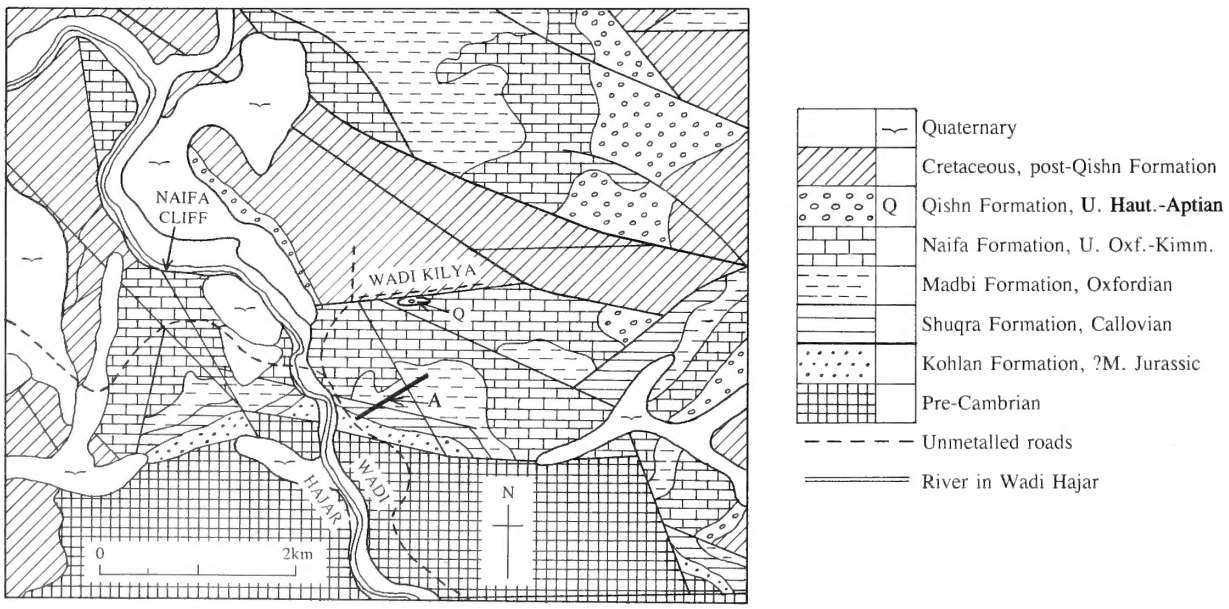


Fig. 4 Geological map of the area around Al Ma'abir, Naifa Cliff and Wadi Kilya. The Wadi Kilya section of Fig. 5 is on the southern side of the Qishn Formation capped hill on the south side of Wadi Kilya. The section through the top Kohlan, Shuqra and Madbi Formations is at **A** south of Wadi Kilya.

and many brachiopods, bivalves and gastropods were obtained from the Shuqra and Madbi Formations (Fig. 6).

Jebel Billum

The long arcuate outcrop of sedimentary Jurassic rocks at Jebel Billum is about 10 km long. It overlies Precambrian metamorphic and igneous rocks (and basalts that are probably Lower/Middle Jurassic in age) to the south-west, and is followed by the Qishn Formation, then higher Cretaceous rocks and massive Tertiary limestones to the north-east (Fig. 7). The peak of Jebel Billum itself is formed by Palaeocene limestones of the Umm-er-Radhuma Formation. In the north-western part of the outcrop, a cliff in the upper part of the Jurassic (Fig. 8) lies south-west of that peak. Here the Naifa and Hajar Formations are overlain by the Qishn Formation, the contact with the latter being readily recognizable by the sharp colour change from grey to reddish-brown near the top of the cliff. The top of the Madbi Formation occurs at the base of the cliff, and the overlying Billum Member is 60 m thick, extending up to a prominent white limestone (Fig. 10). The Kilya Member has a middle limestone section between more marly beds above and below, as at Wadi Kilya, but the exact position of the disconformable contact with the Arus Member is uncertain owing to lack of access. It is at or some distance below the prominent beds of massive grey limestone near the top of the cliff which are overlain by the more sandy reddish-brown beds of the Qishn Formation. The lower Billum Member part of this cliff extends westwards to the road-cutting at the western entrance to the Jebel Billum inlier, where it forms an overhanging cliff, which was the vantage point for the photograph of Fig. 8 (also Beydoun's (1964: pl. 9, lower) photograph; note that on his photograph he placed the 'Naifa'/Qishn 'unconformity' at the position of the Billum/Kilya Member contact). The *Glochiceras* and *Orthosphinctes* shown in the bottom half of the Billum Member in Fig. 12 were collected from material excavated from this western road-cutting entrance to Jebel Billum.

From the front of Jebel Billum, the cliff of Naifa and Hajar Formations extends south-eastwards for several kilometres forming long cliffs, near the top of which the Qishn contact is readily seen from the sharp colour change to reddish-brown. The unconformity between Naifa and Hajar Formations (ie. at the contact between the Kilya Member and the Arus Member) is also well seen, especially in the long easternmost cliff. At the base of this cliff near its eastern end (Fig. 11; at locality PC on Fig. 7) many perisphinctids occur 7–8 m above the base of the Billum Member. Many are fragments or moulds of large specimens on limestone blocks and are neither well-preserved nor collectable. Several photographs and some specimens were obtained (list on Fig. 12), and they form the main evidence for the dating of the bottom of the Billum Member as Upper Oxfordian.

A succession that is more difficult to interpret is in a steep bank and cliff on the north side of the road just before it leaves the eastern end of the Jebel Billum outcrop (locality EJB on Fig. 7). The *Orbitolina* Limestone of the Qishn Formation forms a small cliff at the top of the bank, and parts of the underlying Arus Member are exposed in the bank below, including the contact with the Kilya Member, which can be clearly seen to be an unconformity here. The bulk of the Kilya Member is obscured, but at the western end of the outcrop the whole thickness of the Billum Member is well seen. The main interest, however, is in the Arus Member, which is 61.5 m thick here, and in the 13.8 m of the Mintaq Member up to the disconformity at the base of the Qishn Formation (Fig. 12). The Mintaq Member has two horizons with ammonites: an upper bed of marls only 5 m below the Qishn with crushed *Substeueroceras*, and a lower bed of porcellanous limestones with many ammonites including *Virgatosphinctes, Choicensisphinctes, Substeueroceras* and *Blanfordiceras*. Both faunas are from the upper half of the Upper Tithonian, and the upper one is important in providing evidence for the age of the beds immediately below the Qishn Formation in Jebel Billum. The underlying shales and marls of the Arus Member contain similar ammonites in a bed of rubbly limestone just below the middle of the member (Fig. 12), and the age is somewhat lower in the Upper Tithonian. A single specimen of *Crioceratites* from the basal bed of the Qishn Formation here is the first evidence for an Upper Hauterivian date for the bottom of that formation. No ammonites were found in the Kilya Member at this locality, nor have they been found anywhere else in the Jebel Billum inlier, though there are large areas of outcrop where they might be expected, all of which are difficult to reach (eg. the flanks of the main Jurassic cliff in Figs 8, 10).

The Kohlan, Shuqra and Madbi Formations are well exposed in the valley (part of Wadi Ghiadhat) below the main Jurassic cliff in Jebel Billum, and there are places where the contact with the metamorphosed basement igneous rocks is seen. The upper half of the Shuqra and the Madbi Formations were measured here, and large collections were made of the immensely rich brachiopod faunas. Bivalves and gastropods are also abundant at some horizons, and there is a bed containing large specimens of the nautiloid *Paracenoceras* near the top of the Shuqra Formation (Fig. 6).

Wadi Arus

4 km west of the western road entrance to the Jebel Billum inlier the road descends into the upper end of Wadi Arus through a gorge that exposes the full thickness of the Mintaq Member of the Hajar Formation (Fig. 7). At the bottom the road turns northwards into the wider part of Wadi Arus and after 1 km passes a prominent cliff on the west exposing a bed of large microbialite boulders near the top (Figs 13, 15). There are cliffs on both sides of the wadi here, and correlation between them poses difficulties, though it appears that the lowest limestone in the eastern cliff can be traced continuously across the wadi and the unmetalled road to the middle of the western cliff (Fig. 16). A short distance to the north a complex low-angle fault system brings the Cretaceous down to the bottom of the wadi and the Jurassic is not seen again farther north. Little visited this locality and published vertical sections of the western cliffs (Little, 1925: pl. 25) showing the fault and beds up the wadi to the south, though it is not possible to identify the cliff with the microbialite boulders on his sections. He also gave a section (1925: pl. 26) of the eastern cliffs, marking a bed of 'oil shales', which he said correlated with a similar bed at Naifa Cliff. This is near the bottom of the lowest exposure in the eastern cliffs shown on Fig. 16, and being near the base of the Kilya Member, Little's correlation is nearly correct. Beydoun also visited these exposures, and collected ammonites from the Breadloaf Concretions on the east side (which he said belonged to the Madbi Formation) and also a few from the top of the Billum Member (which he said was part of the Shuqra Formation) (Beydoun, 1964: 35, 36), but he made no reference to the bed of large microbialite boulders in the western cliff.

The upper part of the Billum Member is seen in a small cliff just south of that west cliff (Fig. 13, lower left), and its top bed containing many crushed impressions of *Streblites* and perisphinctids forms the pavement at the bottom of the main cliff (Fig. 15). In the west cliff there is a thickness 12.4 m of pale grey marls and limestones of the Kilya Member up to a clear disconformity at the base of the Arus Member of the Hajar Formation. The bottom bed of the Arus Member consists of darker yellow-brown marls and limestones containing many strings and cross-bedded veins of gypsum, as well as scattered microbialite boulders. On the south side of the western

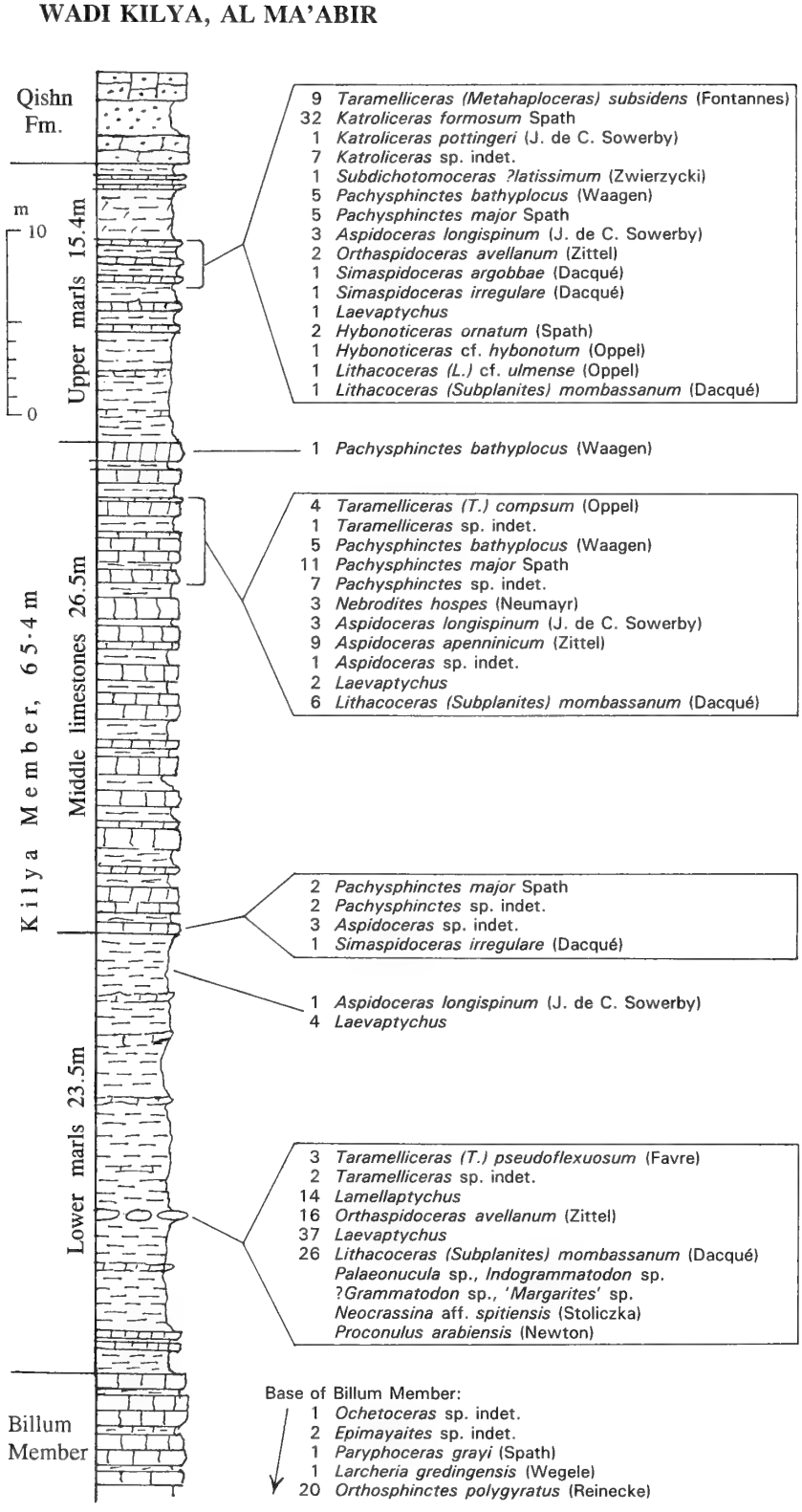


Fig. 5 Vertical section of the Naifa Formation at Wadi Kilya, Al Ma'abir (see Fig. 4 for location).

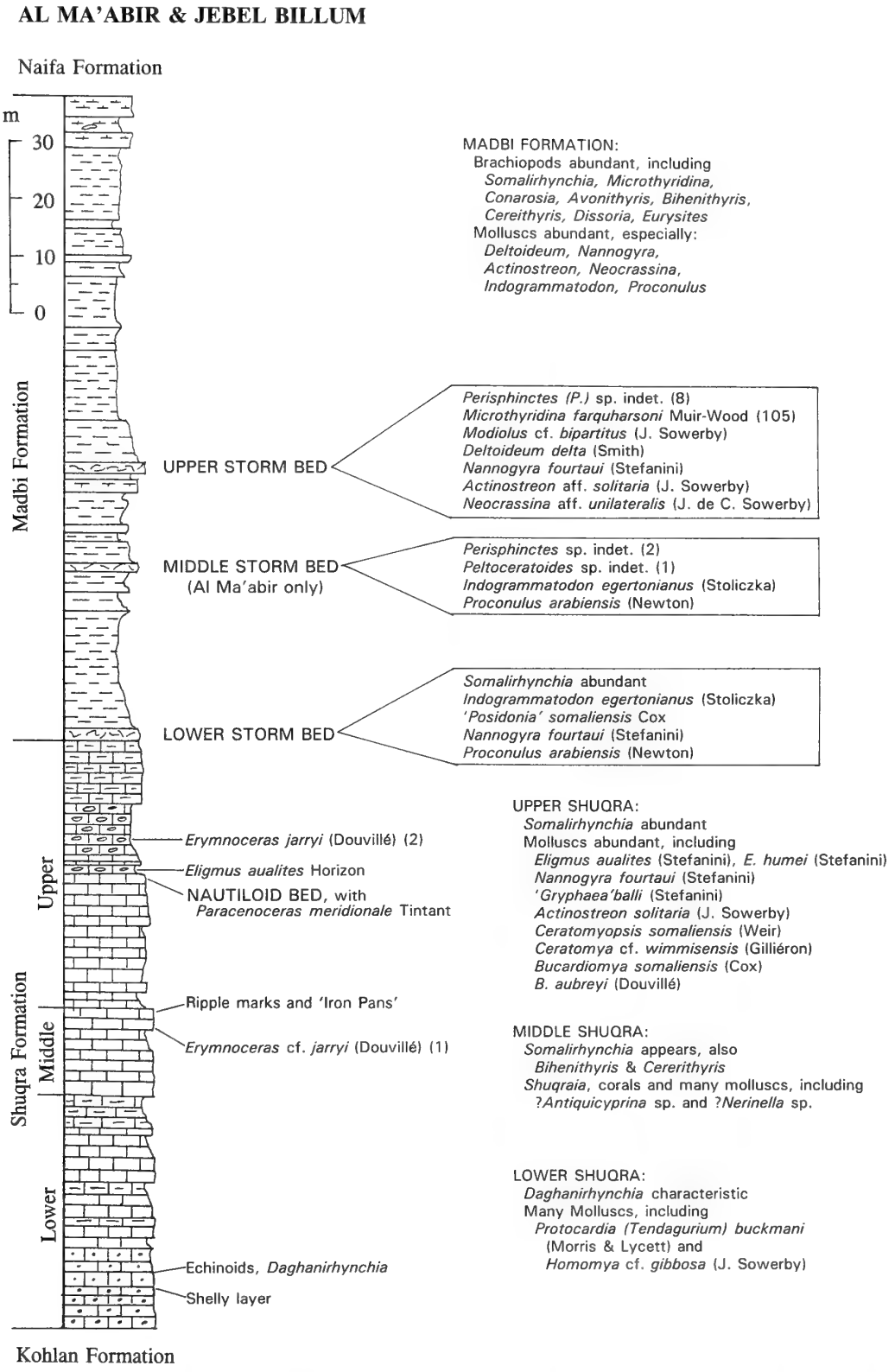


Fig. 6 Vertical section of the Shuqra and Madbi Formations in central Jebel Billum and from 0.6 km SE of the Al Ma'abir road/river crossing to 1 km eastwards; thicknesses of the Madbi and the Upper Shuqra are taken from the Jebel Billum section, while thicknesses of the Middle and Lower Shuqra are taken from the Al Ma'abir area; the Madbi Formation below the Middle Storm Bed is faulted out at Al Ma'abir.

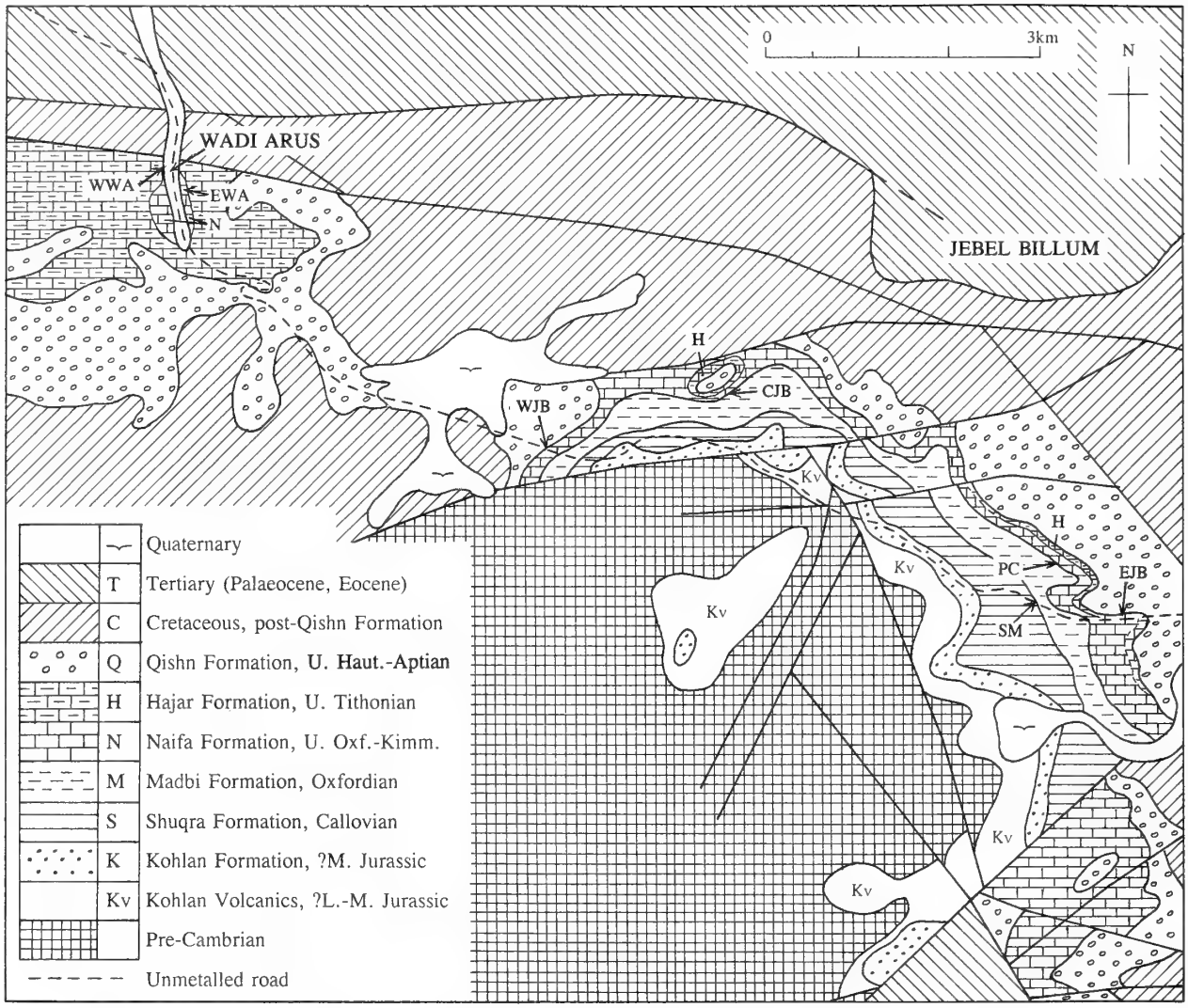


Fig. 7 Geological map of Jebel Billum and Wadi Arus. **EWA** and **WWA** are the locations of the east and west cliffs in Wadi Arus of Figs 13, 15, 16; **WJB** is the western road entrance to Jebel Billum; **CJB** is the main Jurassic cliff section of central Jebel Billum, photographed from the western entrance in Fig. 8, and in detail in Fig. 10; **PC** (Perisphinctid Cliff) is the long cliff (shown in Fig. 11) with perisphinctids low in the Billum Member at its base; **EJB** (Eastern Jebel Billum) is the section on the north side of the road where it first enters eastern Jebel Billum, depicted in the upper half of Fig. 12; **SM** is the exposure of the Shuqra and Madbi Formations in east Jebel Billum, 1 km SW of the Perisphinctid Cliff.

cliff access can be gained to the Kilya/Arus contact, where it is seen to be an angular unconformity, the irregular bottom of the Arus Member cutting down into the eroded top of the Kilya Member. Access can also be obtained here to the scattered boulders in this bottom bed and to the main 2.4 m thick bed of boulders. A rich basal Upper Tithonian ammonite fauna was obtained from these boulders (Fig. 17), mainly from 2.4 m bed of large microbialite boulders, but the same ammonites also occur in the smaller boulders that are scattered through the bed below down to the base of the Arus Member. The whole ammonite fauna is new to Yemen, and includes the remarkable discovery of two large examples of the boreal ammonite *Riasanites rjasanensis* (Lahusen), the only record of this genus in the Tethyan Province except in Argentina, and at a considerably older horizon than its topmost Tithonian to Berriasian age in the Boreal Province. Beds have apparently slumped and slipped along low angle planes at the top of this west cliff, and it is not clear how much (if any) of the Mintaq Member is present higher up before Cretaceous rocks are emplaced (?by slumping).

The succession in the eastern cliff is considerably different: the two points of correlation are the bed of microbialite boulders, which are clearly the same on both sides of the wadi, and the limestone that is the lowest horizon exposed on the eastern side (Fig. 16). Above the latter limestone there are 35 m of marls and limestones of the Kilya Member up to the base of the Arus, which are not seen in the west side cliff, having been cut out by sliding, slumping or erosion. Near the middle of the Kilya Member as developed in this eastern cliff there are marls containing the Breadloaf Concretions, from which a rich Upper Kimmeridgian, Beckeri Zone, ammonite fauna was collected. It is similar to the fauna from the lower part of the Kilya Member in Wadi Kilya and at Naifa Cliff. In fact, 2.5 m above the base of the Kilya Member in the eastern cliff there is an horizon of widely scattered, large (1 m diameter × 0.5 m thick) grey limestone

doggers, which are so similar to the large doggers 7.5 m above the base of the Kilya Member in Naifa Cliff (Fig. 3), that a direct lithological correlation between them might be postulated. The microbialite boulders in the eastern cliff contain the same ammonites as in the boulders of the west cliff, and above them are 40.9 m of marls and limestones before much more massive limestones are reached that mark the base of the Mintaq Member. These can be traced continuously along the cliff to the south, then up the road gorge out of the wadi to the south-east up to the base of the Qishn Formation, making a total thickness of 85 m of Mintaq Member (Fig. 18). There are huge slumped blocks of these Mintaq Member limestones on the south side of the road gorge, especially at its lower end where it turns into the wadi, which are seen in a photograph published by Beydoun (1964: pl. 11). Most of the limestones contain no ammonites (or other fossils), but about 31 m below the top there is a bed containing abundant crushed *Substeueroceras* and a few *Protacanthodiscus*, which give an Upper Tithonian or basal Berriasian age to this part of the Mintaq Formation. Still higher, about 16 m below the Qishn Formation, a very large (0.5 m diameter) *Aspidoceras* was seen and photographed, though it could not be collected.

The Mintaq Salt Dome

About 50 km farther up Wadi Hajar to the north-west is an area where Jurassic rocks outcrop in three small salt domes. The first of these is the Mintaq Salt Dome, 8 km beyond Sidara, in which the Mintaq Member has been pushed into an orientation with vertical bedding around the periphery of the dome, by rising gypsum and halite deposits in the underlying Sabatayn Formation. There are two main outcrops of the Mintaq Member here, the south-western and north-eastern outcrops, separated by the core of the dome in which there are two plugs of Recent basalts (Fig. 19). The south-western outcrop gives a continuous measurable succession from its contact with the Sabatayn evaporites, through 215.7 m of limestones with subsidiary marls, up to its contact with the overlying Qishn Formation, where a disconformity misses out part of the Berriasian, the Valanginian, and Lower Hauterivian stages (Fig. 20). The upper two-thirds of the Mintaq Member and its contact with the Qishn Formation are well exposed in a gulley (Fig. 14; at locality X on Fig. 19), near the bottom end of which a rich ammonite fauna was collected from beds 27–77. A few ammonites occur sporadically in higher and lower beds. All are new to Yemen and are of mid-Berriasian age. Of particular interest is the abundance of the Tethyan ammonite *Spiticeras* and the South American Berriasian genus *Argentiniceras*. There are no ammonites in the top 64 m of the Mintaq Member, the age of which, though probably still Berriasian, is not known accurately. The ammonite-bearing beds were not located on the hillside east of the main gulley (Fig. 14, background at top right), nor were they located during a search of the extensive north-eastern outcrop of the Mintaq Member in the salt dome. The latter outcrop appears to expose the same beds as in the south-western outcrop, and there are large areas of exposure of vertical or slightly overturned beds on a high 1 km long NW-SE trending ridge, up to a contact with a small area of Qishn Formation.

LITHOSTRATIGRAPHY AND BIOSTRATIGRAPHY

The Kohlan Formation

LITHOLOGY AND TYPE SECTION. The term Kohlan Formation was first used by Beydoun (1964: 31), being derived from the 'Kohlan Series' of Lamare (1930: 52), which was proposed for the arenaceous beds at the base of the Jurassic on the high plateau at Kohlan, 75 km NW of Sana'a. At that type locality the formation consists of about 250 m of conglomerates, sandstones and sandy marls, with plant impressions in the top 30 m. Beydoun (1968: 64) took the section about 1 km SE of the river crossing at Al Ma'abir as the reference section and location for the Kohlan Formation in Wadi Hajar, where it is about 55 m thick and lies directly on eroded and peneplaned basement rocks. At the top it is overlain conformably by the Shuqra Formation, the base of which is placed at the bottom of the lowest bed of calcified sandstone that shows evidence of marine conditions, bioturbation and contains some shelly layers. The Kohlan Formation is also well exposed in the central part of the Jebel Billum inlier, and a photograph of its contact with the Precambrian basement was given by Beydoun (1964: 44, pl. 8, upper figure). According to the German Geological Map (explanation of sheet D-39-61/73) the basal sedimentary Jurassic rocks in the Jebel Billum inlier are underlain by tuffs and basalt and trachyte lavas, that are themselves of Jurassic age. The evidence for the Jurassic (rather than Precambrian) age of these igneous rocks is not known to us.

At both Al Ma'abir and Jebel Billum the Kohlan Formation consists of coarse-grained sandstones, pebble beds and conglomerates, with a few horizons of finer silts and silty marls in the upper part. The conglomerates contain many boulders and pebbles of the basement beds, cross-bedding is frequent, some beds are cut by quartz seams, and there are haemetite cemented patches in the upper beds. The formation is probably fluviatile or estuarine throughout.

BIOSTRATIGRAPHY. There is no fossil evidence for the date of the Kohlan Formation in Wadi Hajar or most other areas of Yemen. In the Dhufar region of Oman, immediately east of Yemen, the occurrence of a fossil plant low in the formation suggests that it might be of Lower Jurassic age at that level (Beydoun, 1964: 46; 1968: 65). The date of the top of the formation is delimited by the age of the base of the overlying Shuqra Formation, and the only new evidence we have to add is the occurrence of three species of echinoids near the base of the Shuqra. These and the abundant faunas of *Daghanirhynchia* immediately above, are Bathonian or Lower Callovian in age, which suggests that the top of the Kohlan Formation might lie within the Bathonian.

The Shuqra Formation

LITHOLOGY AND TYPE SECTION. After the earlier use of the term 'Shuqra Limestone', the name Shuqra Formation was first used by Beydoun (1964: 31–35; 1968: 105–07) for a calcareous formation above the arenaceous Kohlan Formation and below the argillaceous Madbi Formation. The type locality is at Jebel Urays, 15 km north of Shuqra, and 80 km north-east of Aden, where it follows the Kohlan Formation unconformably, and consists of 98 m of limestones, truncated at the top by Tertiary basalts.

The Shuqra Formation is well exposed in the wadi below the main Jurassic cliff in central Jebel Billum, where it is conformable with both the Kohlan Formation below and the Madbi Formation above, and is about 100 m thick. At Al Ma'abir the Shuqra Formation occurs 1 km south-east of the river crossing, and is about 70 m thick, where it follows the Kohlan Formation conformably, but the upper part is only partly exposed and the contact with the Madbi is faulted.

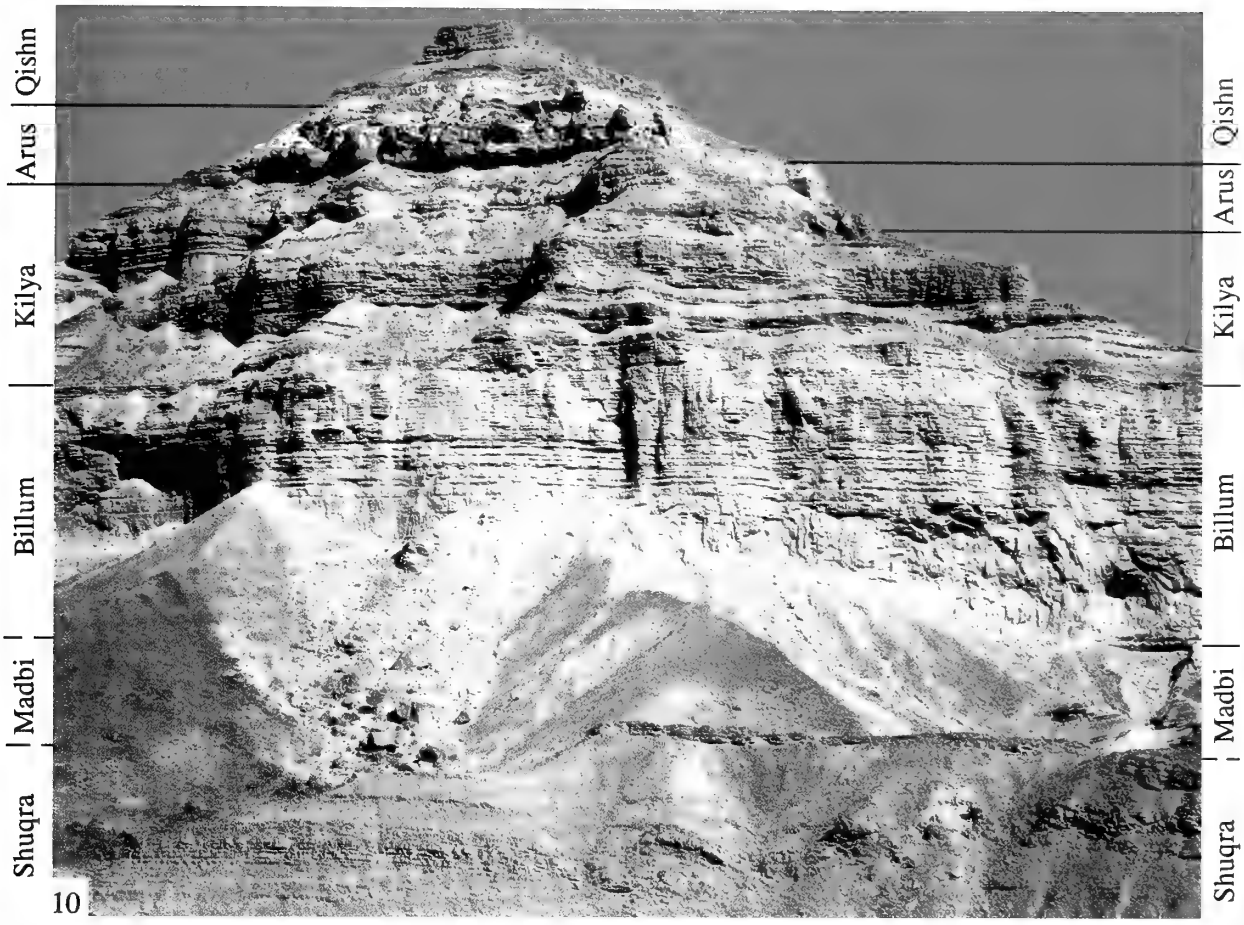
The Shuqra Formation is calcareous throughout, though the limestones are nodular, rubbly or marly at some horizons, and it is sandy in the lower part, where the basal beds are transitional from the Kohlan Formation. The middle part is more heavily calcified and has more massive, fine-grained limestones. At the top it ends with a bed with ripple marks then a ferruginous surface at Al Ma'abir and two

Fig. 8 The main Jurassic cliff, central Jebel Billum; the peak of Jebel Billum consists of Palaeocene Limestone of the Umm-er-Radhuma Formation; the vertical cliff in the foreground is formed by the Naifa and Hajar Formations, and is capped by the Qishn Formation (see Fig. 10 for detail).

Fig. 9 The type locality of the Naifa Formation at Naifa Cliff; most of the beds are the middle and upper parts of the Billum Member; the Kilya Member is the highest cliff in shadow on the extreme right.

Fig. 10 Detail of the main Jurassic cliff (at CJB on Fig. 7) on the southern side of Jebel Billum; owing to the difficulty of access, the exact position of the unconformity between the Kilya and Arus Members is uncertain.

Fig. 11 The Perisphinctid Cliff in eastern Jebel Billum (at PC on Fig. 7); most of the cliff consists of Naifa and Hajar Formations overlain by Qishn Formation at the top; Madbi Formation is exposed at the base of the cliff on the left, and perisphinctid ammonites occur low in the Billum member at the base of the cliff in the centre of the photograph.


Qishn
Arus
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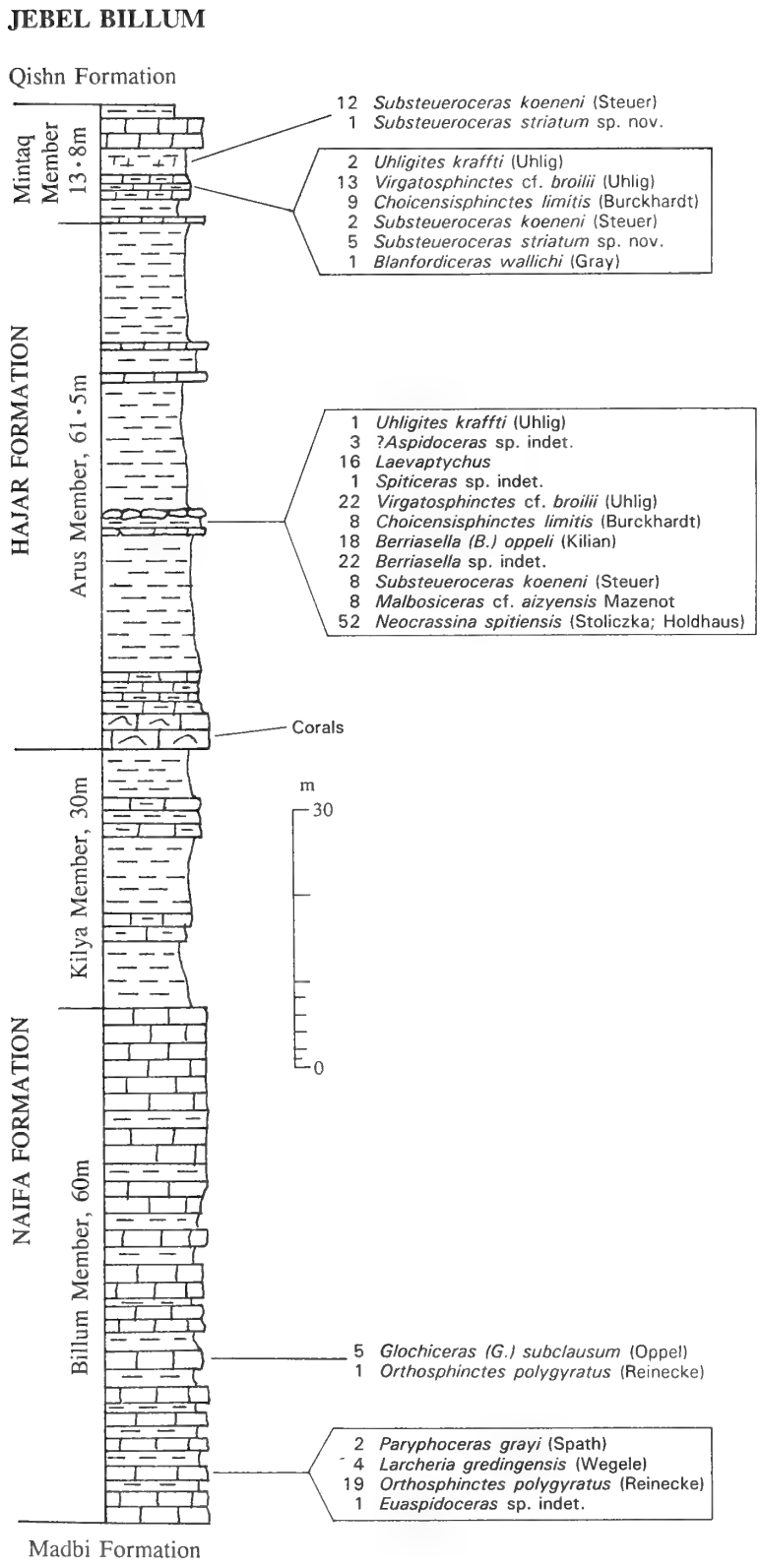


Fig. 12 Vertical section of the Naifa and Hajar Formations in Jebel Billum; the upper half was obtained from the Eastern Jebel Billum locality (EJB on Fig. 7), the lower half from the nearby Perisphinctid Cliff (PC on Fig. 7); the 5 *Glochiceras* and 1 *Orthosphinctes* 18–20 m above the base of the Billum Member were collected in the western entrance road cutting to Jebel Billum.

ferruginous surfaces ('Iron Pans') at central Jebel Billum. This middle part is conveniently divided off as the Middle Shuqra, leaving the more marly limestones of the Upper and Lower Shuqra above and below. The ripple-marks and the 'Iron Pans' marking the top surface were formed during a period of emergence above sea-level. The Middle Shuqra, as so defined, is about 15 m thick at both Al Ma'abir and central Jebel Billum.

BIOSTRATIGRAPHY. The discovery of three specimens of the ammonite *Erymnoceras (Pachyerymnoceras) jarryi* (Douvillé) is important for dating the Shuqra Formation. Two were found 17 m below the top of the Upper Shuqra in the sections at central Jebel Billum and south-east of Al Ma'abir, and the third was in the top part of the Middle Shuqra at the latter locality (Fig. 6). They date the middle and upper parts of the Shuqra as Middle Callovian or low Upper Callovian. No other ammonites have been recorded from the Shuqra. Also of interest is a 0.5 m thick bed of limestone 23 m below the top of the formation in central Jebel Billum, which contains many large, solid, well-preserved specimens of the nautiloid *Paracenoceras meridionale* Tintant; *P. calloviense* (Oppel) occurs at a similar horizon at Al Ma'abir. Both are Callovian in age.

Brachiopods are abundant in the Shuqra Formation. In the Lower Shuqra they are dominated by two or three species of *Daghaniryhnchia*, which are characteristic of this horizon. *Bihenithyris* and *Cererithyris* occur in smaller numbers and there are a few *Conarosia* and *Arabicella*. *Somalirhynchia* appears in the Middle Shuqra, where it is the most abundant brachiopod, and is accompanied by smaller numbers of *Bihenithyris* and *Cererithyris*. In the Upper Shuqra, *Somalirhynchia* remains the most abundant brachiopod, now occurring together with substantial numbers of *Conarosia, Arabicella, Arapsopleurum* and *Cererithyris*, and occasional *Arapsothyris* and *Ptyctothyris*. Though generally Callovian in age, these brachiopods are not well-dated independently elsewhere, except that *Somalirhynchia* is not thought to occur below the Middle Callovian, which is the probable date of the Middle Shuqra.

Several specimens of *Acrosalenia wyvillei* Currie, *Hemicidaris gregoryi* Currie and *Metacrosalenia pseudocidaroides* (Currie) were found near the base of the Shuqra Formation at Al Ma'abir, and although they are Bathonian or Callovian in age elsewhere, these echinoids cannot be dated more precisely.

Many bivalves and gastropods are found in the Shuqra Formation, as seen in the long lists in the appendix. They include the genus *Eligmus*, of which *E. aualites* (Stefanini) is especially common in an horizon 0–2 m above the Nautilus Bed in central Jebel Billum (Fig. 6). *Eligmus* ranges up to the top few metres of the Shuqra, but it does not pass up into the Madbi Formation. The stratigraphical range of *Eligmus* is not thought to extend higher than the top of the Callovian, so, together with the presence of *Erymnoceras*, it is good evidence that the top of the Shuqra Formation is near to the Callovian/Oxfordian boundary.

The Madbi Formation

LITHOLOGY AND TYPE SECTION. The name was proposed by Beydoun (1964: 31–36; see also 1968: 68) from its development on Jebel Madbi, where it was described as an essentially argillaceous formation of marls and shales, between the calcareous Shuqra Formation below and calcareous Naifa Formation above. Beydoun recorded a thickness of 252 m on Jebel Madbi. However, he did not recognize that the limestones that come in approximately 100 m above the base are the limestones of the Naifa Formation (Billum Member). So approximately the upper 152 m of his 252 m thickness on Jebel Madbi is the Naifa Formation, closely similar to its development at Naifa Cliff and Wadi Kilya, and the argillaceous beds of the restricted Madbi Formation on Jebel Madbi are about 100 m thick.

The Madbi Formation is well-developed in Jebel Billum, where it is 111.5 m thick, and also east of the road south-east of the Al Ma'abir river crossing, where it is about 70 m thick. It is argillaceous throughout, and though marls are more common than shales, only occasionally are they sufficiently calcareous to form harder beds of rubbly or marly limestone. A few horizons are silty, gypsiferous or bituminous. The formation is highly fossiliferous, with abundant 'shelly' faunas of brachiopods, bivalves and gastropods. There are also many belemnites, but ammonites are rare and generally fragmentary and poorly preserved. A feature of the Madbi Formation at both Jebel Billum and Al Ma'abir is the 'storm beds': the lowest one, 1–2 m thick, forms the bottom bed of the formation in central Jebel Billum, but is cut out by faulting at Al Ma'abir, while there is another one up to 4 m thick and 16 m higher at Al Ma'abir, and a top one 2 m thick and 43 m higher at central Jebel Billum. They are dark brown, ferruginous, rubbly marls, containing immense numbers of poorly sorted brachiopods, bivalves, oysters, gastropods and belemnites, all heaped up in an unsorted mass as if thrown together by storms (?or by earthquake induced slumping).

BIOSTRATIGRAPHY. The Madbi Formation is Lower and Middle Oxfordian in age: the age of the top is delimited by the Bimammatum Zone, Upper Oxfordian, ammonites in the bottom few metres of the overlying Naifa Formation, while the age of the base cannot be older than the Middle or Upper Callovian date given by the ammonites in the upper part of the Shuqra Formation. Age evidence from the ammonites in the Madbi Formation itself consists of a *Peltoceratoides* in the Middle Storm Bed and *Perisphinctes* in the Upper Storm Bed, both at Al Ma'abir, which suggest a Lower and Middle Oxfordian age respectively. The Shuqra/Madbi Formation junction is probably close to the Callovian/Oxfordian boundary.

Very large numbers of brachiopods occur in the Madbi Formation, especially in the Storm Beds, but they are not well-dated independently elsewhere, and being potentially facies dependent, they do not give a better age assessment of the formation. As in the Middle and Upper Shuqra, *Somalirhynchia* is abundant, and there are now representative species of *Conarosia, Avonithyris, Bihenithyris, Cererithyris, Dissoria, Eurysites, Mycerosia* and *Ptyctothyris*. *Microthyridina* appears in considerable numbers in the Upper Storm Bed at about the middle of the formation, and a few *Somalithyris* appear in the upper part of the formation.

Bivalves and gastropods are also abundant in the Madbi Formation. Many genera continue from the Shuqra Formation, except *Eligmus* which is now absent, and are joined by *Indogrammatodon, Neocrassina* and other genera.

The Naifa Formation

LITHOLOGY AND TYPE SECTIONS. After its description in an unpublished Iraq Petroleum Company report by Pike & Wofford in 1939, the first published accounts of the Naifa Formation were by Beydoun (1964: 31–46; 1968: 80). He designated the section at Naifa Cliff on the south (right) bank of the river, 2 km upstream from the road/river crossing at Al Ma'abir as the type locality. The middle two-thirds of the formation are seen here (Figs 3, 9): the top was removed by erosion before deposition of Quaternary rocks, while the base is seen in nearby sections at the Al Ma'abir road/river crossing and at Wadi Kilya.

The Naifa Formation is essentially calcareous: thick, hard limestones in the lower half, are followed by marls and limestones in the upper half. This slight difference in lithology is the basis of its division into two members, the lower Billum Member and the upper Kilya Member, which are newly proposed here.

Fig. 13 Cliff section on the west side of Wadi Arus; the upper part of the Billum Member forms the low cliff at bottom left, while its top bed forms the limestone platform at the base of the main cliff; the disconformity between the Kilya and Arus Members occurs half way up the face of the main cliff (see Fig. 15 for details).

Fig. 14 The near-vertical beds of the middle part of the Mintaq Member exposed in a gulley in the south-western outcrop of the Mintaq Salt Dome; bed 60, in which most ammonites were found, is the vertical limestone immediately to the left of the tree at the right hand edge of the photograph; the section extends upwards to the left, and the prominent limestone near the lower left edge of the photograph is bed 98.

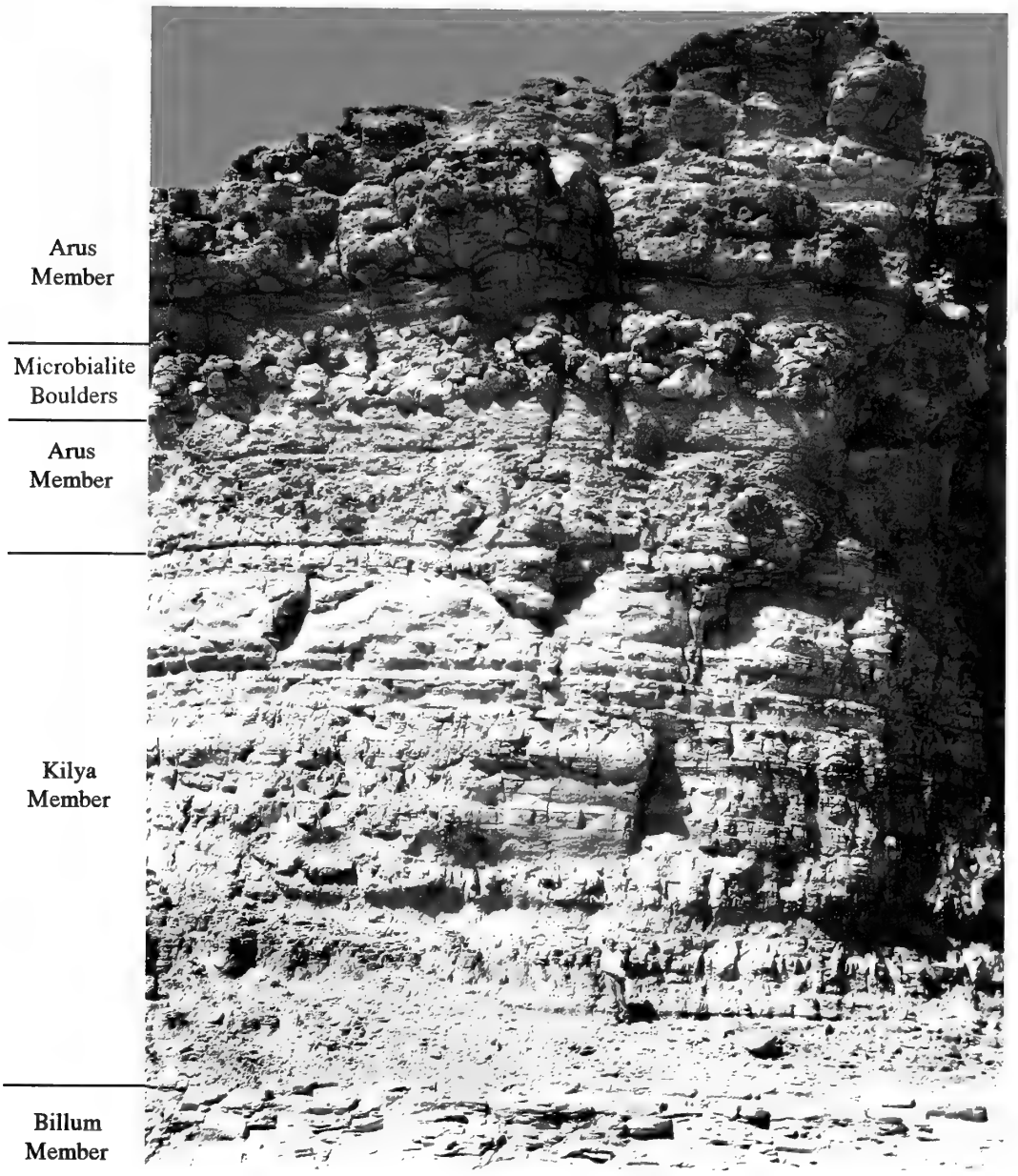


Fig. 15 Detail of the face of the cliff on the west side of Wadi Arus. The figure (1.75 m tall) at the base of the cliff gives a rough scale.

The **Billum Member** is named after its type locality in the lower half of the long cliff in eastern Jebel Billum (Fig. 7, locality PC; Fig. 11), where its basal contact with the Madbi Formation is seen at the bottom of the cliff. It is 60 m thick here, and consists of beds of limestone averaging 0.5 m thick, alternating with thinner beds of marly, flaggy limestone. The Billum Member forms the lowest vertical part of the main cliff in central Jebel Billum (Figs 8, 10), and is cut through in the western road entrance to the Jebel Billum inlier. Approximately the top two-thirds of the Billum Member is exposed in Naifa Cliff. The Billum Member is also seen in a long cliff south of the main section of the Kilya Member on the hillside south of Wadi Kilya, and its basal contact is well exposed here.

The **Kilya Member** is named after its type section on the Qishn-capped hill south of Wadi Kilya, 2 km E by S of Naifa Cliff, which is its most complete development, being 65.4 m thick up to the disconformity at the base of the Qishn Formation (Fig. 5). It contains more marls than the Billum Member, and is subdivided into three parts: marls and thin limestones of the lower and upper parts are separated by a middle part in which thicker limestones are dominant, similar to those of the Billum Member. In Naifa Cliff the lower and middle parts are present but the upper part is missing; ammonite collections were obtained from six horizons, and the lower marly part contains a notable bed of large (0.5 m thick × 1 m diameter) scattered doggers of hard grey limestone (Fig. 3). In Jebel Billum exposures are poor or difficult to reach, but there are good exposures in the cliffs on both sides of Wadi Arus, where the lower marly part

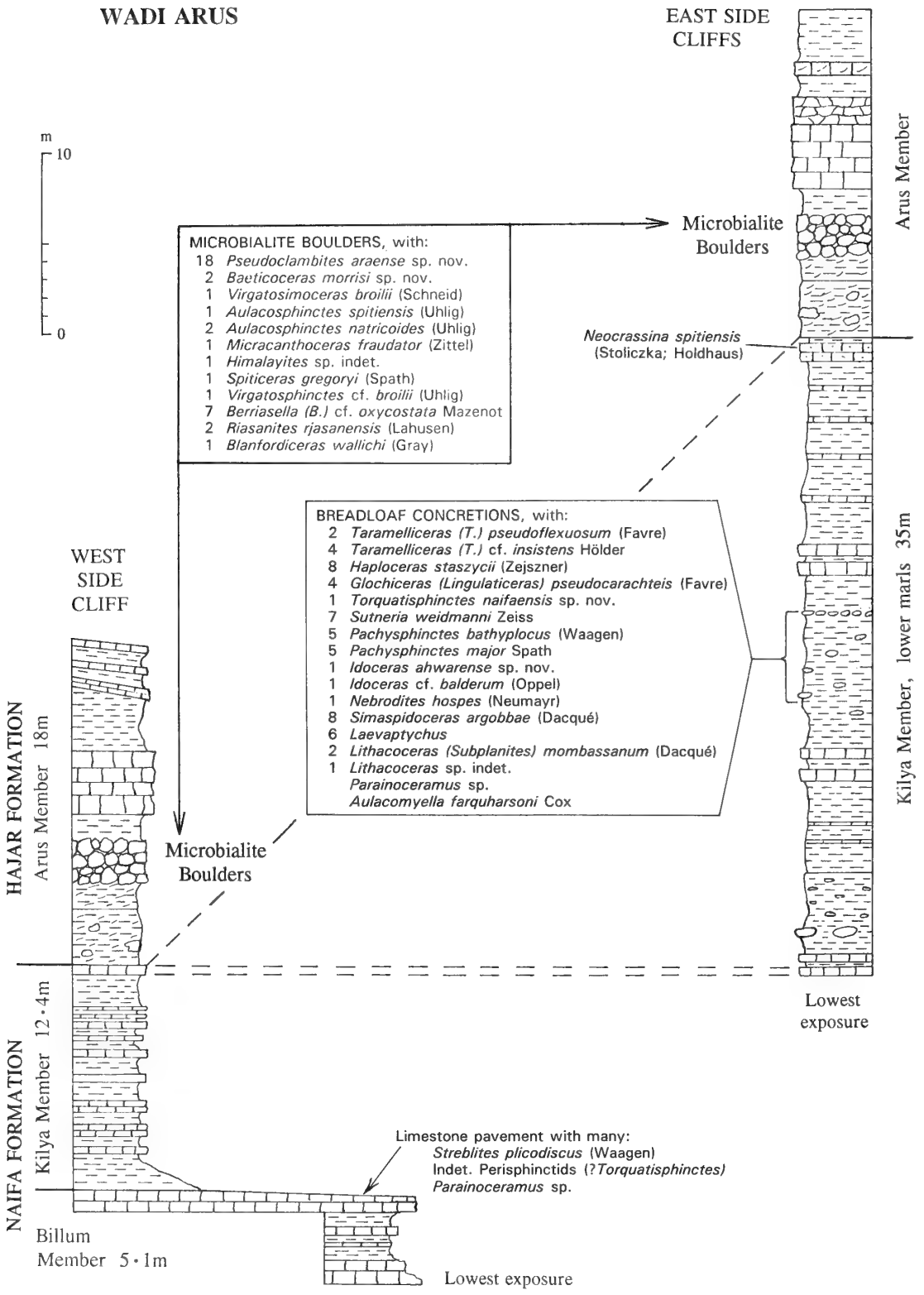


Fig. 16 Vertical sections comparing successions in the Kilya and Arus Members in the opposite east and west cliffs in Wadi Arus.

contains the Breadloaf Concretions (0.25 m × 0.25 m × 0.15 m concretions of hard grey limestone), and also a bed of much larger scattered limestone doggers that may be the same as the bed of similar large doggers in Naifa Cliff.

BIOSTRATIGRAPHY. The age of the Naifa Formation is from the Bimammatum Zone, Upper Oxfordian, to the lower half or two-thirds of the Hybonotum Zone, Lower Tithonian. The contact between the Billum and Kilya Members is at the junction between the Eudoxus and Beckeri Zones or within the lower part of the Beckeri Zone.

1. The Billum Member. The lowest ammonite fauna in the Billum Member occurs in the bottom 5 m in the cliff south of the Wadi Kilya section, and 7–8 m above the base of the member at the base of the Perisphinctid Cliff in eastern Jebel Billum (Figs 5, 12). More than 50 specimens were obtained, belonging to the genera *Ochetoceras, Epimayaites, Larcheria, Paryphoceras, Orthosphinctes* and *Euaspidoceras*, which date the beds as Bimammatum Zone, Upper Oxfordian.

18–20 m above the base of the Billum Member in the road cutting at the western entrance to Jebel Billum *Glochiceras (G.) subclausum* (Oppel) and *Orthosphinctes polygyratus* (Reinecke) were collected (Fig. 12), which indicate a similar Bimammatum Zone age.

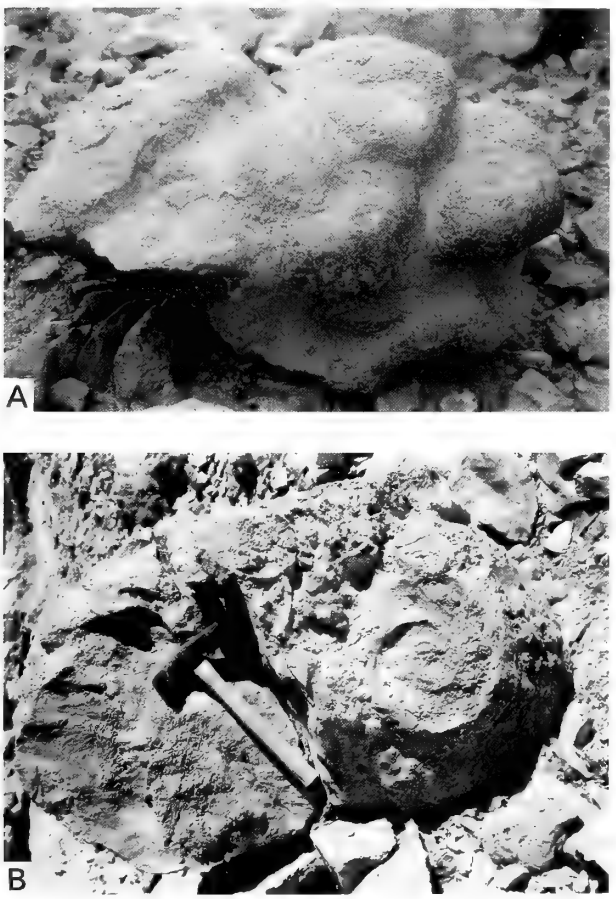


Fig. 17 Microbialite boulders from the bottom of the Arus Formation in Wadi Arus; **A** is a complete boulder with an unbroken upper surface; **B** is a similar boulder broken through the middle showing cross sections of several ammonites; the hammer handle is 34cm long and gives the scale for both photographs.

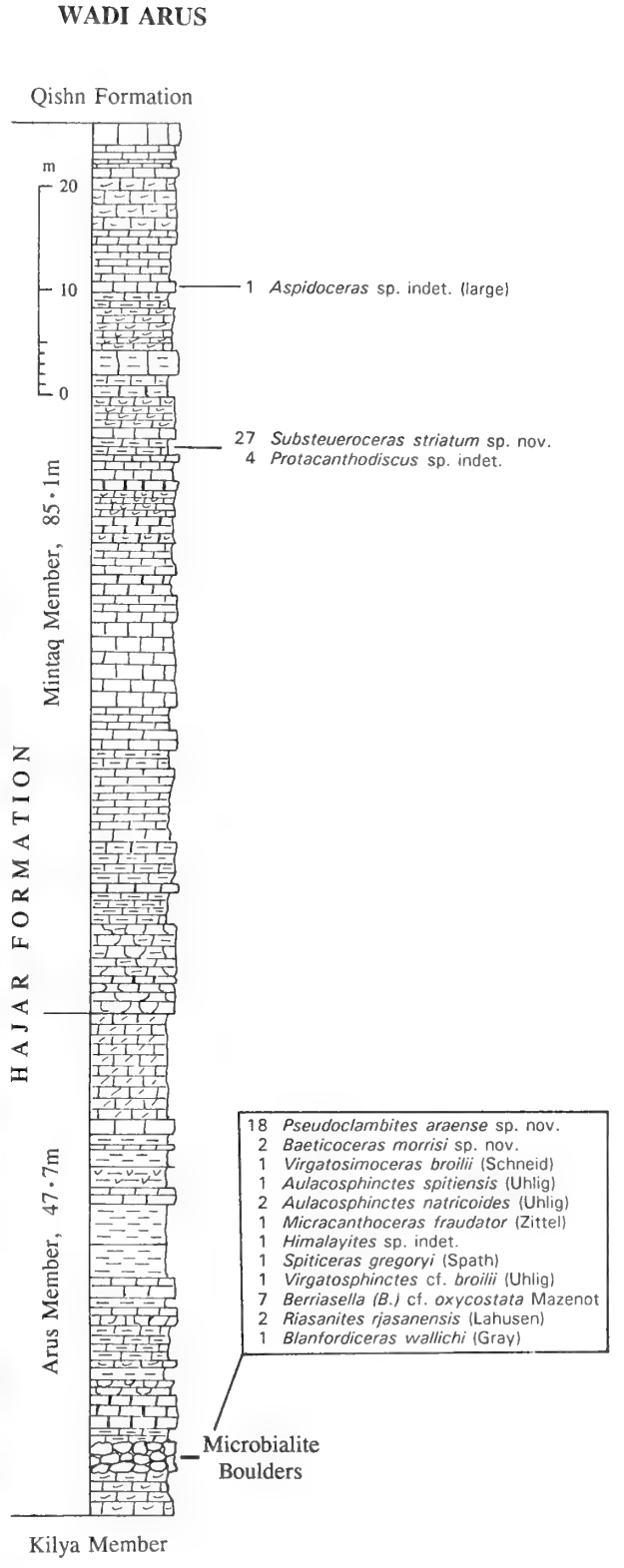
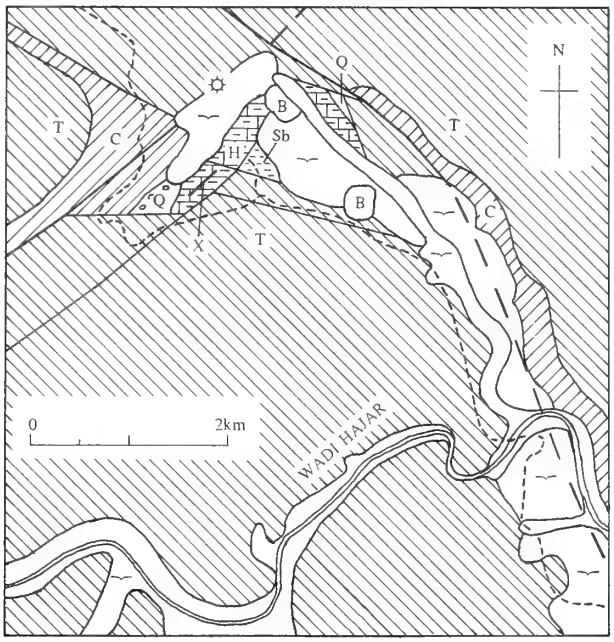


Fig. 18 Vertical section of the full succession of the Hajar Formation in Wadi Arus.



	~	Quaternary
	B	Basalt, Quaternary
	T	Tertiary (Palaeocene, Eocene)
	C	Cretaceous, post-Qishn Formation
	Q	Qishn Formation, U. Haut.-Aptian
	H	Hajar Formation, Berriasian
	Sb	Sabatayn Formation
– – – – –		Unmetalled roads
═══		River in Wadi Hajar
☼		Hot spring

Fig. 19 Geological Map of the Mintaq Salt Dome; **X** is the position of the succession in Figs 14 and 20.

Evidence for the age of the upper part of the Billum Member comes from the large specimen of *Crussoliceras* cf. *wegelei* Enay found in a limestone about 8 m below the top of the member in a roadside cliff east of the Al Ma'abir road/river crossing (Fig. 3), which is of Divisum Zone, Lower Kimmeridgian, date.

The top bed of limestone of the Billum Member forms a pavement below the west side cliff in Wadi Arus and many crushed *Streblites* and indeterminate perisphinctids, some of which are probably *Torquatisphinctes*, can be seen on the surface (Fig. 16). These are of Eudoxus or Beckeri Zone, Upper Kimmeridgian, age.

The abundant brachiopods in the Shuqra and Madbi Formations disappear in the higher formations, except in the lower part of the Billum Member where there are two 0.3 m thick marly limestones, the '*Microthyridina* Beds', 4 m and 9.3 m above the base of the member and well seen at the base of the Perisphinctid Cliff in east Jebel Billum, that contain many large examples of *Microthyridina farquharsoni* Muir-Wood, accompanied by a few *Kallirhynchia* and *Somalirhynchia*. No brachiopods were found higher in the Billum Member.

Bivalves and gastropods are also much less common above the top of the Madbi Formation, though some occur in 'shell beds' and at a few other horizons, such as the '*Microthyridina* Beds' in the bottom 4–9 m of the Billum Member.

2. The Kilya Member. This member is dated as Beckeri Zone, Upper Kimmeridgian, and Hybonotum Zone, Lower Tithonian. The Beckeri Zone is represented by a very rich and mainly well-preserved ammonite fauna found in Wadi Kilya, Naifa Cliff and Wadi Arus. More than 250 ammonites of the following genera were collected: *Taramelliceras, Haploceras, Glochiceras, Torquatisphinctes, Sutneria, Pachysphinctes, Idoceras, Nebrodites, Aspidoceras, Orthaspidoceras, Simaspidoceras* and *Lithacoceras*, and more than 75 *Lamellaptychus* (belonging to *Taramelliceras*) and *Laevaptychus* (from Aspidoceratidae). These ammonites occur at the different horizons in the lower marly and middle limestone parts of the Kilya Member that are shown in detail on Figs 3, 5 and 16, and include well preserved specimens from the Breadloaf Concretions in Wadi Arus. They are well dated as Beckeri Zone, Upper Kimmeridgian.

The upper marly part of the Kilya Member occurs only at Wadi Kilya (Fig. 5), from where 72 ammonites were obtained, many of them well-preserved, belonging to the genera *Taramelliceras, Katroliceras, Subdichotomoceras, Pachysphinctes, Aspidoceras, Orthaspidoceras, Simaspidoceras, Hybonoticeras* and *Lithacoceras*. There are many species in common with the ammonites in the Beckeri Zone below, but the presence of *Katroliceras, Hybonoticeras* cf. *hybonotum* and *H. ornatum* indicate the Hybonotum Zone, Lower Tithonian. This is the date of the highest fauna in the Kilya Member, and the disconformity between it and the Arus Member consists of the remainder of the Hybonotum Zone (if any) and the next four ammonite zones up to the top of the Lower Tithonian.

Brachiopods are rare in the Kilya Member, with only a few terebratulids (*Ptyctothyris* and ?*Cererithyris*) found in the middle limestones and one *Acanthothiris* in the lower marls. An 'Astarte Bed' with many *Neocrassina* occurs 0.3 m below the top of the lower marly part of the Kilya Member in the east cliff in Wadi Arus.

Hajar Formation

LITHOLOGY AND TYPE SECTIONS. The Hajar Formation is a new name proposed here for the calcareous formation that is separated from the underlying Naifa Formation by an unconformity. It is named after Wadi Hajar, and the type section is in the cliffs on both sides of Wadi Arus. It is essentially calcareous, and is divided into two members, newly proposed here: a lower, thinner Arus Member, consisting of marls, limestones, and concretions, and an upper, much thicker Mintaq Member of more massive limestones. Both members are well-developed and thick in Wadi Arus, but the Mintaq Salt Dome and Jebel Madbi are important sections for the fullest development of the Mintaq Member.

The **Arus Member** is named after its type locality in a prominent cliff on the west side of Wadi Arus, where it has a clear contact with the Kilya Member of the Naifa Formation, which it follows after an unconformity that misses out the whole of the Lower Tithonian except for part of its lowest zone (Figs 13, 15, 16). It consists of marls with gypsum and scattered microbialite boulders, then a thick bed of large microbialite boulders, followed by more marls and limestones. The top is better seen in the opposite east cliff where the complete thickness is 47.7 m.

The **Mintaq Member** is named after the development at its type locality in the south-west outcrop of the Mintaq Salt Dome, where there is a good basal contact with the evaporites of the Sabatayn Formation. It consists of 215.7 m of limestones, that are thick and heavy for the lowest 77 m, then there are subsidiary marls and marly

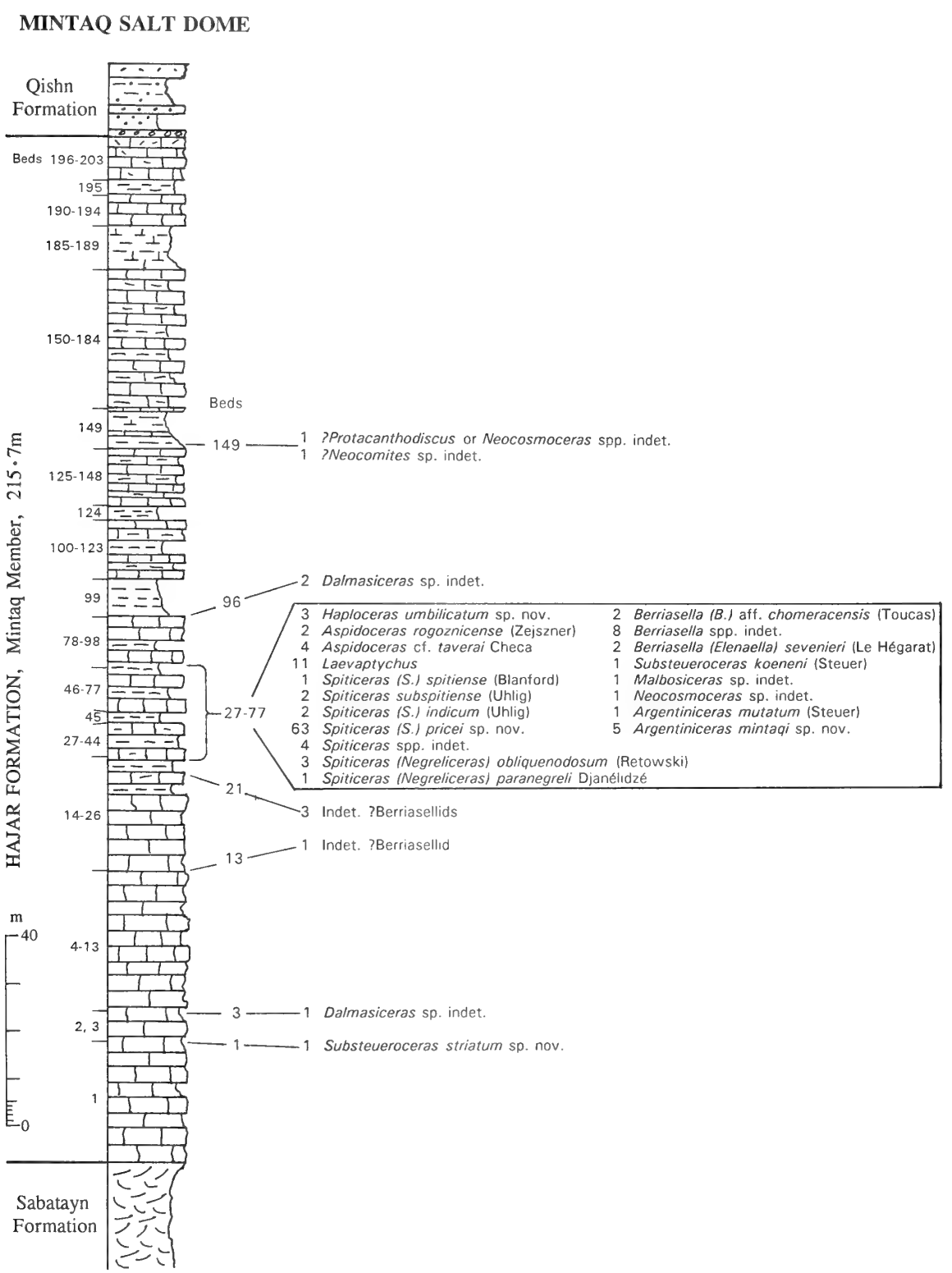


Fig. 20 Vertical section of the Mintaq Member in the south-western outcrop in the Mintaq Salt Dome.

limestones in the remaining 139 m up to a good contact with the overlying Qishn Formation (Figs 14, 19, 20). Another important section of the Mintaq Member is in the east cliff in Wadi Arus (Fig. 18), where it follows the Arus Member conformably, and consists of 85 m of thick limestones, with subsidiary marls and marly limestones, the upper parts of which are well seen in the road gorge leading south-eastwards up out of the wadi. It cannot be proved that the base of the Mintaq Member at Mintaq correlates exactly with the conformable contact between the Arus and Mintaq Members in the east cliff of Wadi Arus, though the gypsum deposits in the Arus Member at Wadi Arus suggests a general correlation with the Sabatayn Formation at Mintaq (see Fig. 2). An even thicker development occurs on Jebel Madbi, where Beydoun recorded 434 m of beds that seem to belong to the Hajar Formation as here defined, and most of that thickness is the Mintaq Member.

BIOSTRATIGRAPHY. The age of the Hajar Formation is from the base of the Upper Tithonian up to about the middle of the Berriasian, the latter date having been proved at Mintaq and Jebel Madbi. The contact between the Arus and Mintaq Members is within the Durangites Zone, probably in the low to middle part of that zone.

1. The Arus Member. The base is well dated in Wadi Arus, where 38 ammonites were obtained from the microbialite boulders (Figs 16, 17) belonging to the genera *Pseudoclambites, Baeticoceras, Virgatosimoceras, Aulacosphinctes, Micracanthoceras, Himalayites, Spiticeras, Virgatosphinctes, Berriasella, Riasanites* and *Blanfordiceras*. All these genera are confined to the Upper Tithonian or younger, except *Virgatosphinctes* and *Virgatosimoceras* which also occur in the Lower Tithonian. The date of the microbialite boulders is Microcanthum Zone, Upper Tithonian. *Baeticoceras morrisi* sp. nov. is most probably of basal Microcanthum Zone age, deduced from its morphological features and probable relationships with other species of the genus, but some of the other ammonites are better placed higher in the Microcanthum Zone, suggesting that the microbialite boulders might be a condensed horizon. Noteworthy are two examples of the mainly Boreal species *Riasanites rjasanensis* (Lahusen), and the rare ammonite *Pseudoclambites* which is poorly known elsewhere.

An ammonite fauna that is almost completely different from that in the microbialite boulders in Wadi Arus occurs in the lower to middle part of the Arus Member in eastern Jebel Billum (Fig. 12). 91 ammonites were obtained belonging to the genera *Uhligites, ?Aspidoceras, Spiticeras, Virgatosphinctes, Choicensisphinctes, Berriasella, Substeueroceras* and *Malbosiceras*, as well as 16 *Laevaptychus* (aptychi from Aspidoceratidae). The commonest genus is *Berriasella* (with 40 specimens collected), and the age is Durangites Zone, Upper Tithonian, from the presence of *Malbosiceras* and *Substeueroceras*. This is slightly younger than the date of the microbialite boulders in Wadi Arus.

The only brachiopods seen in the Arus Member were two specimens of an unidentified smooth terebratulid in the microbialite boulders in Wadi Arus. Molluscs occur in the shell just below the middle of the Arus Member in east Jebel Billum, especially the astartid *Neocrassina*, and there are a few bivalves and gastropods in the Coral Bed at the base of the Arus Member in the same section.

2. The Mintaq Member. The base is well exposed in eastern Jebel Billum where 45 ammonites were collected in the basal 6 m (Fig. 12), belonging to the genera *Uhligites, Virgatosphinctes, Choicensisphinctes, Substeueroceras* and *Blanfordiceras*. Although these are only slightly different from the ammonites 40 m below in the Arus Member in the same section, *Substeueroceras* makes up a higher proportion of the total, and with *Blanfordiceras*, suggests a slightly higher horizon in the Durangites Zone for the base of the Mintaq Member.

Few ammonites were found in the Mintaq Member in Wadi Arus, but a limestone in the upper half contains many crushed *Substeueroceras striatus* sp. nov. and *Protacanthodiscus*. sp. indet., and a large *Aspidoceras* sp. indet. was photographed nearer the top of the member. These are either Durangites Zone, Upper Tithonian, or Euxinus Zone, lower Berriasian, in age. This might also be the date of the lowest ammonites (*Substeueroceras* and *Dalmasiceras*) in beds 1 and 3 in the Mintaq Salt Dome (Fig. 20).

The main evidence for the Berriasian age of much of the Mintaq Member comes from rich ammonite fauna in the middle part of the member at Mintaq (Fig. 20), where 108 specimens were collected of the genera *Haploceras, Aspidoceras, Spiticeras, Berriasella, Substeueroceras, Malbosiceras, Neocosmoceras, Dalmasiceras*, and *Argentiniceras*, and 11 *Laevaptychus*.

The presence of *Argentiniceras*, a rich and varied fauna of *Spiticeras* including typical well-developed species, and two species of *Berriasella, B. (B.) chomeraciensis* (Toucas) and *B. (Elenaella) sevenieri* (Le Hégarat), give an Occitanica Zone age, close to or just below the middle of the Berriasian.

Finally, two *Tirnovella occitanica* (Pictet) collected by Dr John Smewing from near the top of the Mintaq Member on the summit of Jebel Madbi, are also of Occitanica Zone, mid-Berriasian, age, though they might be slightly higher in that zone than the Mintaq ammonites. The age of the top of the Hajar Formation on Jebel Madbi is not known, but is likely to be in the upper part of the Berriasian.

No brachiopods or identifiable bivalves and gastropods were found in the Mintaq Member, except for a few poorly preserved bivalves in the base of the member in east Jebel Billum.

Qishn Formation

LITHOLOGY AND TYPE SECTIONS. The type locality of the Qishn Formation is at Ras Sharwayn, near Qishn, 290 km ENE of Mukalla, where it is 411 m thick and consists of brecciated limestone at the base, followed by limestones and marls, then hard crystalline limestones containing *Orbitolina* in the upper half (Beydoun, 1968: 91). A similar section in Wadi Masila, 70 km to the west, reaches a total thickness of 498 m. In the Wadi Hajar and Mukalla areas the formation is much thinner, being only 54.5 m thick in Beydoun's reference section at Jabal al Rays, near Mukalla, where there is a conglomerate at the base, then marls and sandstones, and the *Orbitolina* Limestone is 17.5 m thick at the top. Two sections measured by us in Wadi Hajar are in east Jebel Billum and at the Mintaq Salt Dome. In east Jebel Billum the 31.9 m thick Qishn Formation is at the top of the cliff immediately above the section shown in Fig. 12; it consists of 5 m of shelly, cross-bedded, calcified sandstones and silts, then 17.3 m of marls, mudstones and marly limestones, up to the 9.6 m thick hard *Orbitolina* Limestone at the top. In the whole of the Jebel Billum inlier, the red-brown basal beds of the Qishn Formation make an easily recognizable colour change near the top of the cliffs of the grey Naifa and Hajar Formations. In the Mintaq Salt Dome the Qishn Formation is 77.8 m thick: 0.8 m of conglomeratic sandstone at the base, passes into sandstones, silts and mudstones 69.4 m thick, including two oyster beds, up to the massive *Orbitolina* Limestone 7.6 m thick at the top.

BIOSTRATIGRAPHY. The main reason for including the Qishn Formation in this description is to record the discovery of a single example of the ammonite *Crioceratites (C.) villiersianum* (d'Orbigny) in the east Jebel Billum section (Howarth, 1998: 98, pl. 23, fig. 2). Although found lying loose at the top of the Hajar

Formation, it had certainly fallen from the shelly sandstone, 5 m thick at the base of the Qishn Formation immediately above. It is Upper Hauterivian in age, and is the first date obtained for this basal part of the formation. The *Orbitolina* Limestone is generally recognized to be Upper Barremian in age from the foraminifera (*Palorbitolina lenticularis* (Blumenbach) and *Choffatella decipiens* Schlumberger) that it contains (Beydoun, 1968: 92). Three ammonites were recorded by Beydoun, 1968: 93) from the upper half of the 498 m thick Qishn Formation in the Wadi Masila section referred to above: *Cheloniceras (C.) cornuelianus* (d'Orbigny) (BMNH C.86982; figured Howarth, 1998, pl. 21, fig. 3), *Cheloniceras (C.)* sp. indet. (BMNH C.86983, recorded as *C. martini* (d'Orbigny) by Beydoun; figured Howarth, 1998, pl. 21, fig. 4) and ?*Cheloniceras* (BMNH C.71676, recorded as *Douvilleiceras* sp.), which all indicate an Upper Aptian age at that level. However, the specimen of *Crioceratites* from the base of the formation is a whole stage earlier than previous dates obtained for the Qishn Formation.

CORRELATION WITH EAST AFRICA

The Jurassic and Cretaceous rocks of Yemen and Somalia were deposited before the opening of the Gulf of Aden, which commenced with rifting in the Oligocene followed by sea-floor spreading from the late Miocene onwards (Abbate *et al*, 1988: 440–442). The geology of the southern coastal areas of Yemen and northern Somalia was described and compared by Beydoun (1970), from whose work the diagram of Fig. 21 was drawn, using the best-fit of the pre-rifted structures. The best described Jurassic sequence in northern Somalia is near Bihendula, which can be seen from Fig. 21 to have been only 225 km south-west of the Wadi Hajar area in the Jurassic, compared with the present-day post-rifting separation of 580 km. The sequence near Bihendula was described by MacFadyen (1933) and the ammonites in the succession were described by Spath (1935). A summary of the age assessments was given by Arkell (1956: 308–312), and a more recent update of the lithostratigraphy, including a vertical section of the succession at Bihendula, can be found in Bosellini (1989: 412 &c, fig. 33). As expected, there is much similarity between the Jurassic sequences of Wadi Hajar and Bihendula, and the following comparison can be made:

WADI HAJAR	BIHENDULA
Hajar Formation	?Gawan Limestone
Naifa Formation, Kilya Member	Daghani Shales
Naifa Formation, Billum Member	Wanderer Limestone
Madbi Formation	Gahodleh Shales
Shuqra Formation	Bihen Limestone
Kohlan Formation	Adigrat Sandstone

The initial correlation is based on similar or near-identical lithology in the two areas, suggesting that they were probably within the same basin of deposition. However, there are differences in relative thicknesses (eg. the Daghani Shales are much thicker (370 m) than the Kilya Member (65 m) or the combined Kilya and Arus Members (113 m)), but the ammonites and other faunas described from the two sequences lend considerable support to this correlation. The most useful ammonites for age dating in Somalia were collected from a section that extended through all the formations, at Daghani, 6 km east of Bihendula, which was described by MacFadyen (1933: 28) and Spath (1935: 206–208). The correlation given above is not the same as the correlation suggested by Beydoun (1964: 45, table 4), which was not based on a comparison of the ammonite faunas in the two areas.

The Kohlan and the Adigrat Sandstone are similar arenaceous

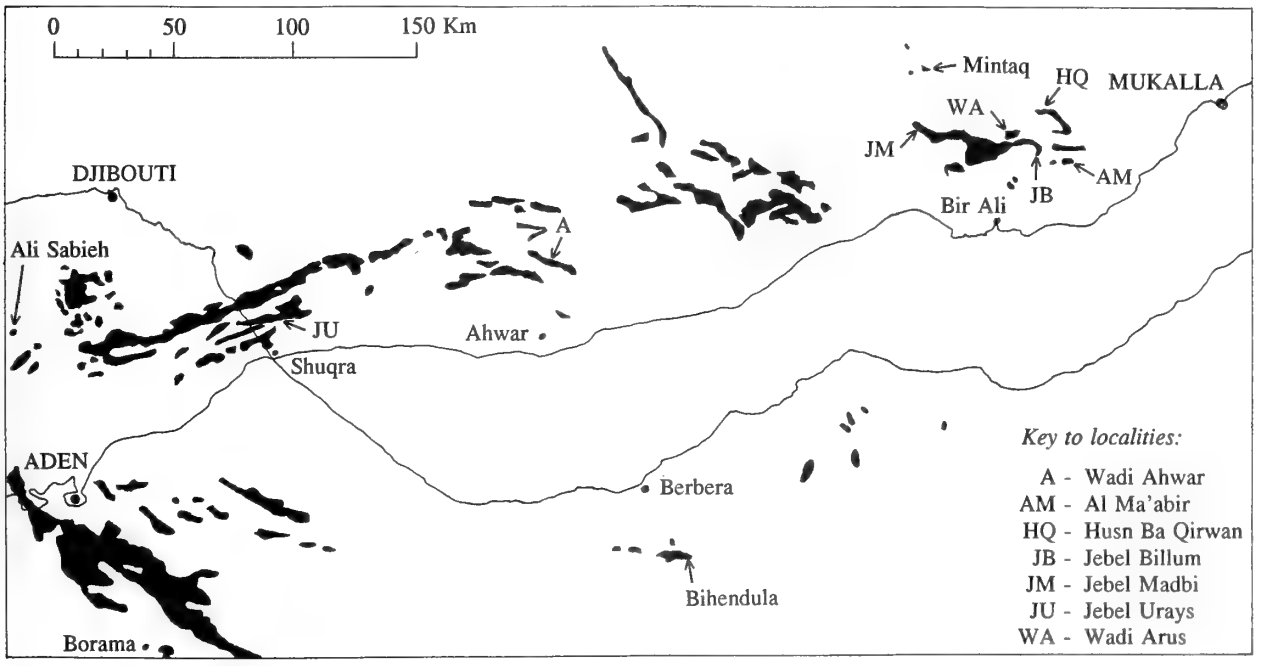


Fig. 21 The Jurassic outcrops in Wadi Hajar and northern Somalia, showing their relative position before the formation of the Gulf of Aden in the Miocene. Outcrops of Jurassic are shown in solid black. Redrawn from Beydoun, 1970, figs 2–4; the fit between Yemen and Somalia is at the 500 fathom (approx. 1000 m) isobath, which leads to a minimum (and very small) amount of superposition of Basement, Mesozoic and recent volcanic rocks in the overlap triangle between Aden and Djibouti.

formations, both mainly non-marine and difficult to date, though both probably range from late Triassic (Adigrat Sandstone) or Lower Jurassic (Kohlan Formation) to Middle Jurassic (probably Bathonian).

The Shuqra Formation and Bihen Limestone contain rich, near-identical faunas of brachiopods, molluscs and some echinoids, but rare mid-Callovian ammonites occur in the Shuqra Formation, and a loose Upper Bathonian *Paracenoceras* and a loose Upper Callovian or Lower Oxfordian *Pachyceras* are probably both from the Bihen Limestone.

The Madbi Formation and Gahodleh Shales are both argillaceous formations of Oxfordian age, though excluding the highest part of that stage, as deduced from the poor ammonites in the Madbi and the ages of the adjacent formations in both areas. Both formations contain many of the same brachiopods and molluscs.

The Naifa Formation, Billum Member, and the Wanderer Limestone contain several similar or identical ammonites. There are many difficult-to-determine crushed perisphinctids of Upper Oxfordian or lowest Kimmeridgian appearance in the Wanderer Limestone, but the presence of *Orthosphinctes polygyratus* (Reinecke) and a *?Larcheria* dates at least part of it to the Bimammatum Zone, Upper Oxfordian, as in the lowest part of the Billum Member. Other ammonites in the Wanderer Limestone might be higher in the Kimmeridgian, but there is nothing that is definitely determinable as being of the same age as the Eudoxus or Beckeri Zone ammonites at the top of the Billum Member.

The Kilya Member and the Daghani Shales both contain ammonites from the Beckeri Zone at the top of the Kimmeridgian. Others in the Daghani Shales could be lower in the Kimmeridgian (*Torquatisphinctes, Idoceras, Sutneria* and some aspidoceratids), while it cannot be proved that the Daghani Shales extends up into the Lower Tithonian, like the Kilya Member. Nevertheless, the two formations are similar in age, and better preserved ammonites would be needed from Somalia to make a more exact comparison.

The Hajar Formation and the Gawan Limestone represent a return to more calcareous conditions of deposition in both areas. The two formations might be similar in age, and Spath's (1935: 206) determinations of the poorly-preserved ammonites in the Gawan Limestone as *Aulacosphinctes, Anavirgatites, Pseudovirgatites, Sublithacoceras* and *Simoceras* certainly indicate a Tithonian age, though they could be Lower Tithonian, so it is not possible to show an exact equivalence with the Hajar Formation. The disconformity that excludes most of the Lower Tithonian in Wadi Hajar in Yemen might be absent, or it might be present at a lower biostratigraphical horizon, in Somalia, and the absence of any ammonites in the top 142 m of the Gawan Limestone means that neither the Upper Tithonian nor the Berriasian can be proved to be present in that formation. The correlation of the Hajar Formation and the Gawan Limestone is still tentative, and further progress also requires better ammonites from Somalia.

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APPENDIX

Macrofossils collected in Wadi Hajar. Ammonites identified by M.K. Howarth, brachiopods by Dr E.F. Owen, echinoderms by Dr Andrew Smith, and bivalves and gastropods by N.J. Morris. The bed numbers listed for the Mintaq section refer to those in the vertical section of Fig. 20. Numbers in square brackets are the number of specimens collected.

Naifa Cliff (N14°16'38" E48°32'52")

Naifa Formation, Kilya Member:

Marly limestone, 41.5 m above base. Ammonites: *Pachysphinctes* spp. indet. [15], *Aspidoceras longispinum* (J. de C.Sowerby) [2].

Limestone and marl, 0.4 m thick, 22.0–22.4 m above base; the main ammonite bed in Naifa Cliff. Ammonites: *Taramelliceras* sp. indet. [2], *Lamellaptychus* [6], *Pachysphinctes bathyplocus* (Waagen) [21], *Pachysphinctes major* Spath [23], *Pachysphinctes mahokondobeyrichi* (Dietrich) [5], *Idoceras* cf. *hararinum* Venzo [1], *Aspidoceras longispinum* (J. de C. Sowerby) [3], *Aspidoceras* or *Orthaspidoceras* sp. indet. [1], *Simaspidoceras argobbae* (Dacqué) [1], *Laevaptychus* [7], *Lithacoceras (L.)* cf. *ulmense* (Oppel) [1], *Lithacoceras (Subplanites) mombassanum* (Dacqué) [4]. **Bivalves:** *Palaeonucula* sp. [14].

Limestone 19 m above base. Ammonites: *Orthaspidoceras gortanii* (Venzo) [5].

Row of limestone nodules in marl band, 16 m above base. Ammonites: *Pachysphinctes bathyplocus* (Waagen) [1]; *Simaspidoceras argobbae* (Dacqué) [4]; *Simaspidoceras irregulare* (Dacqué) [1].

Calcareous mudstone, 13.4 m above base. Ammonites: *Torquatisphinctes naifaensis* sp. nov. [7].

Marls, 12 m above base. Bivalves: *Parainoceramus* sp. [1], *Liostrea* sp. [1].

Limestone, 1.4 m above base. Perisphinctid indet. [1].

Naifa Formation, Billum Member:

Shell Bed, 12 m below top. Bivalves: ?*Palaeonucula* sp. [many].

Al Ma'abir road/river crossing, west side (N14°16'05" E48°33'33")

Naifa Formation, Billum Member:

Near base (gently dipping, against cliff). Ammonite: *Ochetoceras* sp. indet. [1]. **Brachiopods:** *Microthyridina farquharsoni* Muir-Wood [13]. **Bivalves:** *Indogrammatodon egertonianus* (Stoliczka) [1], *Modiolus* sp. [2], ?*Limaria* sp. [1], *Nannogyra fourtaui* (Stefanini) [13], *Actinostreon solitaria kindopeensis* (Cox) [8], *Trigonia* sp. [1].

Madbi Formation:

Near top. Bivalves: *Indogrammatodon egertonianus* (Stoliczka) [8], ?*Modiolus* sp., *Nannogyra fourtaui* (Stefanini) [7], *Actinostreon* aff. *solitaria* (J. Sowerby) [2], *Trigonia* sp. [1], ?*Neocrassina* sp. [1], *Colpomya* sp. [1].

Al Ma'abir, new road cutting, 0.5 km east of the road/river crossing

Naifa Formation, Billum Member:

Upper part. Ammonite: *Crussoliceras* cf. *wegelei* Enay [1].

Middle part. Bivalve: *Indogrammatodon egertonianus* (Stoliczka) [1].

Al Ma'abir, from road 0.6 km south-east of river crossing to 1 km eastwards (N14°15'59" E48°34'01")

Madbi Formation:

1 m below top. Bivalves: *Indogrammatodon egertonianus* (Stoliczka) [1], *Limaria* cf. *mandawaensis* Cox [1], *Nannogyra fourteaui* (Stefanini) [2].

Upper Storm Bed, 30 m below top of formation. Ammonites: *Perisphinctes* s.s. sp. indet. [8]. **Brachiopods:** ?*Conarosia* sp. [25], *Microthyridina farquharsoni* Muir-Wood [83]. **Bivalves:** *Indogrammatodon egertonianus* (Stoliczka) [1], *Modiolus* cf. *bipartitus* J. Sowerby [14], *Camptonectes* sp. [3], *'Chlamys'* sp. [1+], *Eopecten* cf. *aubreyi* (Douvillé) [1], *Ctenostreon* sp. [1], *Limaria* cf. *mandawaensis* Cox [7], *Deltoideum delta* (Smith) [20], *Nannogyra fourtaui* (Stefanini) [29], *Actinostreon* aff. *solitaria* (J. Sowerby) [27], *Arctostrea eruca* (Lamarck) [3], *Trigonia* sp. [3], *'Lucina'* sp. [1], ?*Myoconcha* sp. [3], *Neocrassina* aff. *unilateralis* (J. de C. Sowerby) [22], *Pseudotrapezium* sp. of Cox [1], ?*Pleuromya* sp. [1]. **Gastropods:** *Bathrotomaria* sp. [1], *Rhabdoconcha* sp. [5].

36–38 m below top. Brachiopods: *Somalirhynchia africana* Weir [1], *S. arabica* Cooper [38], *S. somalica* (Dacqué) [36], *Avonothyris* sp. [13], *Cererithyris* cf. *wyvillei* (Weir) [8], *Dissoria obscura* Cooper [4], *Eurysites transversus* Cooper [19], ?*Gyrosina* ?sp. nov. [1], *Ornithella* sp. [4], *Ptyctothyris daghaniensis* Muir-Wood [12], *'Terebratula' aulites* Stefanini [4]. **Bivalves:** *Indogrammatodon egertonianus* (Stoliczka) [1], *Arcomytilus* ?sp. nov. [1], *Nannogyra fourtaui* (Stefanini) [2], *Actinostreon* aff. *solitaria* (J. Sowerby) [2], *Trigonia* sp. [1].

Middle Storm Bed, 49 m below top. Ammonites: *Perisphinctes* sp. indet. [2], *Peltoceratoides* sp. indet. [1]. **Brachiopods:** *Daghanirhynchia* sp. [1], *Septirhynchia* sp. (juv.) [1], *Somalirhynchia somalica* (Dacqué) [7], *Bihenithyris deformata* Cooper [5], *Ptyctothyris daghaniensis* Muir-Wood [4]. **Bivalves:** *Palaeonucula* sp. [3], *Indogrammatodon egertonianus* (Stoliczka) [14], *Camptonectes* sp. [1], *Nannogyra fourtaui* (Stefanini) [8], *Actinostreon* aff. *solitaria* (J. Sowerby) [4], *Trigonia* sp. [1], *Neocrassina* aff. *unilateralis* (J. de C. Sowerby) [6]. **Gastropods:** *Proconulus arabiensis* (Newton) [28].

Shuqra Formation:

Upper Shuqra:

Upper part. Bivalves: *'Brachidontes' somalicus* Cox [2], *Modiolus* cf. *bipartitus* J. Sowerby [1], *Eligmus humei* (Stefanini) [2], *E. aualites* (Stefanini) [1], *'Gryphaea' balli* (Stefanini), ?*Myoconcha* sp. [1], *Procyprina hunti* (Cox) [1], *Pseudotrapezium* sp. of Cox [1], *Ceratomyopsis somaliensis* (Weir) [1], *Tellurimya* ?sp. nov. [1], *Bucardiomya somaliensis* (Cox) [1]. **Gastropod:** ?*Rhabdoconcha* sp. [1].

17 m below top, rubbly marls and nodular limestones. Ammonite: *Erymnoceras (Pacherymnoceras) jarryi* (Douvillé) [1].

Loose. Brachiopods: *Somalirhynchia africana* Weir [19], *Somalirhynchia* sp. [32], *Avonothyris* sp. [11], *Cererithyris* sp. [18], *Pleuraloma labiatum* Cooper [1]. **Echinoid:** *Holectypus* sp. [1]. **Crinoid:** ?*Millericrinus* sp. [3].

Middle Shuqra:

2–5 m below top. Ammonite: *Erymnoceras (Pachyerymnoceras)* cf. *jarryi* (Douvillé) [1]. **Brachiopods:** *Somalirhynchia* sp. [13], *Conarosia* sp. [3], *Dissoria obscura* Cooper [10], *'Loboidothyris' aethiopoca* Weir [17]. **Crinoid:** ?*Millericrinus* sp. [2]. **Corals:** (not yet determined). **Stromatoporoid:** *Shuqraia* sp. [1]. **Bivalves:** *'Brachidontes' somalicus* Cox [2], *Modiolus* cf. *bipartitus* J. Sowerby [1], *Eligmus humei* (Stefanini) [2], *Eopecten* cf. *aubreyi* (Douvillé) [2], *'Gryphaea' balli* (Stefanini) [5], *Actinostreon solitaria* (J. Sowerby) [1], *'Lucina'* sp. [1], *Procyprina hunti* (Cox) [2], *Ceratomyopsis somaliensis* (Weir) [2], *Ceratomya* cf. *wimmisensis* (Gilliéron) [1]. **Gastropods:** *Rhabdoconcha* sp. [5], *Ampullospira* sp. [3].

Lower part. Bivalves: ?*Antiquicyprina* sp. [15]. **Gastropods:** ?*Nerinella* sp. [39], ?*Ampullospira* sp. [9].

Lower Shuqra:

28.5 m above base. Brachiopods: *Daghanirhynchia* sp. [2].

15.25 m above base. Bivalves: ?*Palaeonucula* sp. [1], *'Gryphaea' balli* (Stefanini) [2].

10.5 m above base. Brachiopods: *Daghanirhynchia* cf. *macfadyeni* Muir-Wood [16], *D. daghaniensis* Muir-Wood [57]. **Echinoids:** *Acrosalenia wyvillei* Currie [2], *Hemicidaris gregoryi* Currie [1], *Metacrosalenia pseudocidaroides* (Currie) [3]. **Bivalves:** ?*Palaeonucula* sp. [2], *'Gryphaea' balli* Stefanini [1], ?*Procyprina hunti* (Cox) [11], *Pseudotrapezium* sp. of Cox [1], ?*Eomiodon* sp. [1]. **Gastropods:** *Ampullospira* sp. [2].

Loose. Brachiopods: *Daghanirhynchia* cf. *macfadyeni* Muir-Wood

[13], *D. daghaniensis* Muir-Wood [30], *Daghanirhynchia* ?sp. nov. [142], *Arabicella arabis* Cooper [7], *Bihenithyris* cf. *barringtoni* Muir-Wood [33], *B. weiri* Muir-Wood [1], *Cererithyris* sp. [13]. **Bivalves:** ?*Palaeonucula* sp. [1], *Modiolus* cf. *imbricatus* J. Sowerby [4], ?*Bakevellea* sp. [2], *Eligmus* cf. *rollandi* (Douvillé) [1], *Camptonectes* sp. [4], *'Gryphaea' balli* Stefanini [3], ?*Actinostreon* sp. [2], *'Lucina'* sp. [2], ?*Sphaera* sp. [3], *Tendagurium* sp. [13], ?*Antiquicyprina* sp. [1], *Procyprina hunti* (Cox) [11], ?*Eocallista krenkeli* Cox [2], *Bucardiomya somaliensis* (Cox), ?*Homomya* cf. *gibbosa* (J. Sowerby) [1]. **Gastropods:** *Ampullospira* sp. [7], ?*Nerinella* sp. [1].

Wadi Kilya, Al Ma'abir (N14°16'15" E48°34'11").

Collections were made on the southern slope of a hill capped by Qishn Formation on the south side of Wadi Kilya, 2 km E by S of Naifa Cliff.

Qishn Formation:

***Orbitolina* Limestone. Echinoids:** *Holectypus* or *Coenholectypus* sp. [1], ?*Stereocidaris* sp. [1].

Loose, from below *Orbitolina* Limestone. Brachiopods: *Zittelina* sp. ?nov. [12], Terebratulidae [fragments]. **Bivalves:** *Neithea atava* (Roemer) [1], *'Exogyra'* cf. *tuberculifera* Koch & Dunker [7], ?*Amphidonte* sp. [9], *Pholadomya valangiensis* Pictet & Campiche [1]. **Gastropods:** *'Natica'* sp. [11], *Harpagodes* sp. [1], ?*Nerinella* sp. [2].

Naifa Formation, Kilya Member:

Upper Marls: 5–7 m below base of Qishn Formation. Ammonites: *Taramelliceras (Metahaploceras) subsidens* (Fontannes) [9], *Katroliceras formosum* Spath [32], *Katroliceras pottingeri* (J. de C. Sowerby) [1], *Katroliceras* sp. indet. [7], *Subdichotomoceras ?latissimum* (Zwierzycki) [1], *Pachysphinctes bathyplocus* (Waagen) [5], *Pachysphinctes major* Spath [5], *Pachysphinctes* sp. indet. [9], *Aspidoceras longispinum* (J. de C. Sowerby) [3], *Orthaspidoceras avellanum* (Zittel) [2], *Simaspidoceras argobbae* (Dacqué) [1], *Simaspidoceras irregulare* (Dacqué) [1], *Laevaptychus* [1], *Hybonoticeras ornatum* (Spath) [2], *Hybonoticeras* cf. *hybonotum* (Oppel) [1], *Lithacoceras (L.)* cf. *ulmense* (Oppel) [1]. *Lithacoceras (Subplanites) mombassanum* (Dacqué) [1].

Middle limestones:

Top bed. Ammonite: *Pachysphinctes bathyplocus* (Waagen) [1].

3–7 m below top. Ammonites: *Taramelliceras (T.) compsum* (Oppel) [4], *Taramelliceras* sp. indet. [1], *Pachysphinctes bathyplocus* (Waagen) [4], *Pachysphinctes major* Spath [10], *Nebrodites hospes* (Neumayr) (photos only) [3+], *Aspidoceras longispinum* (J. de C. Sowerby) [3], *Aspidoceras apenninicum* (Zittel) [9], *Aspidoceras* sp. indet. [1], *Laevaptychus* [2], *Lithacoceras (Subplanites) mombassanum* (Dacqué) [6]. **Nautiloid:** *Paracenoceras* sp. indet. **Brachiopods:** ?*Cererithyris* sp., *Ptyctothyris* sp. **Bivalves:** *Parainoceramus* sp. [1], *Liostrea* cf. *boloniensis* de Loriol [1].

Basal bed. Ammonites: *Pachysphinctes major* Spath [2]; *Pachysphinctes* sp. indet. [2]; *Aspidoceras* sp. indet. [3]; *Simaspidoceras irregulare* (Dacqué) [1]. **Bivalves:** *Palaeonucula* sp. [6], *Indogrammatodon egertonianus* (Stoliczka) [1], *Neocrassina spitiensis* (Stoliczka [sensu Holdhaus]) [3].

Lower marls:

2 m below top. Ammonites: *Aspidoceras longispinum* (J. de C. Sowerby) [1]; *Laevaptychus* [4].

Row of large doggers 8.5–9 m above base. Ammonites: *Taramelliceras (T.) pseudoflexuosum* (Favre) [3], *Taramelliceras* sp. indet. [2], *Lamellaptychus* [14], *Orthaspidoceras avellanum* (Zittel) [16], *Laevaptychus* [37], *Lithacoceras (Subplanites) mombassanum* (Dacqué) [26]. **Brachiopod:** *Acanthothiris* sp. nov. [1]. **Bivalves:** *Palaeonucula* sp. [ca.70], *Indogrammatodon* sp. [ca.70], ?*Grammatodon* sp. [ca.30], ?*Parainoceramus* sp. [1], *Nannogyra fourtaui* (Stefanini) [1], *'Lucina'* sp. [1], *Neocrassina* aff. *spitiensis* (Stoliczka [sensu Holdhaus]) [35], ?*Trautscholdia* sp. [1], ?*Freiastarte* sp. [4]. **Gastropods:** *Pleurotomaria* sp. [2], *Proconulus arabiensis* (Newton) [22], *'Margarites'* sp. [ca.50], *Pietteia* sp. [14].

Naifa Formation, Billum Member:

Basal 5m. Ammonites: *Epimayaites* sp. indet. [2], *Paryphoceras grayi* (Spath) [1], *Larcheria gredingensis* (Wegele) [1], *Orthosphinctes polygyratus* (Reinecke) [20].

Jebel Billum, eastern end, bank and cliff on north side of road (N14°17'51" E48°29'14")

Qishn Formation:

***Orbitolina* Limestone. Echinoids:** *Allomma* sp. nov. [1], *Heteraster* aff. *oblongus* (Brogniart) [1], *Leptosalenia* sp. [1], *Tetragramma ?variolare* (Brogniart) [1].

Upper part, below *Orbitolina* Limestone. Bivalves: *Lithophaga* sp. [?], *Neithea ?atava* Roemer [3], *'Exogyra'* cf. *tuberculifera* Koch & Dunker [1], ?*Amphidonte* sp. [?]. **Gastropods:** *Pseudonerinea* sp. [1]. ?*Harpagodes* sp. [7].

Middle part. Bivalves: *Cucullaea* sp. [1], *Neithea atava* Roemer [6], *'Exogyra'* cf. *tuberculifera* Koch & Dunker [12], ?*Amphidonte latissima* (Lamarck) [10], ?*Amphidonte* sp. [1], *Linotrigonia* or *Pterotrigonia* sp. [3], *Pholadomya valangiensis* Pictet & Campiche [13]. **Gastropods:** *Harpagodes* sp. [19].

Limestones 3.5 m thick at base of formation. Ammonite: *Crioceratites (C.)* cf. *villiersianum* (d'Orbigny) [1]. **Bivalves:** *Chondrodonta* ?sp. nov. [14]. **Gastropods:** *Harpagodes* sp. [8].

Hajar Formation, Mintaq Member:

Marls, 5.3 m below top. Ammonites: *Substeueroceras koeneni* (Steuer) [12], *Substeueroceras striatum* sp. nov. [1]

Massive limestone, 8.3 m below top. Ammonites: *Uhligites kraffti* (Uhlig) [2], *Virgatosphinctes* cf. *broilii* (Uhlig) [13], *Choicensisphinctes limitis* (Burckhardt) [9], *Substeueroceras koeneni* (Steuer) [2], *Substeueroceras striatum* sp. nov. [5], *Blanfordiceras wallichi* (Gray) [1]. **Bivalves:** ?*Heterodiceras* sp. [2], *Arctostrea hastellata* (Schlotheim) [1].

Hajar Formation, Arus Member:

Marls, 26.5 m above base. Ammonites: *Uhligites* sp. indet. [1], *Aspidoceras* sp. indet. [3], *Laevaptychus* [16], *Spiticeras* sp. indet. [1], *Virgatosphinctes* cf. *broilii* (Uhlig) [22], *Choicensisphinctes limitis* (Burckhardt) [8], *Berriasella (B.) oppeli* (Kilian) [18], *Berriasella* sp. indet. [22], *Substeueroceras koeneni* (Steuer) [8], *Malbosiceras* cf. *aizyensis* Mazenot [8]. **Bivalves:** *Palaeonucula* sp. [2], *Neocrassina* cf. *duboisiana* (d'Orbigny) [1], *Neocrassina spitiensis* (Stoliczka [sensu Holdhaus]) [52].

Basal coral bed; massive colony of fasciculate corals or stromatoporoid *Shuqraia*. Corals [22]. **Bivalves:** *'Gryphaea' balli* (Stefanini) [1], *Arctostrea hastellata* (Schlotheim) [1],

?*Neocrassina* sp. [1]. **Gastropods:** ?*Discotectus* sp. [1], '*Turbo*' sp. [1], ?'*Neritopsis*' sp. [1].

Naifa Formation, Billum Member:

Central part. Bivalves: *Falcimytilus jurensis* (Roemer) [1], *Actinostreon solitaria kindopeensis* (Cox) [6].

Jebel Billum, long eastern Jurassic cliff, Perisphinctid Cliff (N14°18'19" E48°28'35")

Naifa Formation, Billum Member:

Limestone pavement, 7 m above base. Ammonites: *Paryphoceras grayi* (Spath) (photo only) [1], *Larcheria gredingensis* (Wegele) [4, including 1 as photo only], *Orthosphinctes polygyratus* (Reinecke) [19, including 9 as photos only], *Idoceras ahwarense* sp. nov. (loose, ?fallen from higher in Billum Member) [1], *Euaspidoceras* sp. indet. (photo only) [1].

***Microthyridina* Beds, 4 m and 9 m above base. Brachiopods:** *Kallirhynchia* sp. [3], *Somalirhynchia* cf. *arabica* Cooper [4], *Microthyridina farquharsoni* Muir-Wood [50]. **Echinoid:** *Pseudocidaris* aff. *thurmanni* (Agassiz) [1]. **Crinoid:** ?*Millericrinus* sp. [1]. **Bivalves:** *Falcimytilus jurensis* (Roemer) [?], *Indogrammatodon egertonianus* (Stoliczka) [3], *Camptonectes* sp. [2], ?*Limaria* sp. [1], ?*Deltoideum delta* (Smith) [?], *Nannogyra fourtaui* (Stefanini) [7], *Actinostreon solitaria kindopeensis* (Cox) [1], *Trigonia* sp. [3], *Colpomya* sp. [8].

Jebel Billum, east end, 1 km south-west of Perisphinctid Cliff (N14°18'06" E48°28'22")

Shuqra Formation:

Middle Shuqra:

Lower part. Bivalves: '*Brachidontes*' *somalicus* Cox [2], *Pholadomya ?ovalis* (J. Sowerby) [1]. **Gastropod:** *Ampullospira* sp. [1].

Loose. Brachiopods: *Somalirhynchia arabica* Cooper [19], *S. subcircularis* Cooper [8].

Loose, mixed Lower/Middle Shuqra. Brachiopods: *Conarosia* sp. [4], *Daghanirhynchia sulcata* Cooper [15], *Daghanirhynchia* sp. [58], *Bihenithyris bihenensis* Muir-Wood [23], *B. mediocostata* Cooper [4], *Dorsoplicathyris* sp. [13], ?'*Stiphrothyris*' sp. [14]. **Echinoid:** *Acrosalenia (Recrosalenia) somaliensis* Currie [1]. **Bivalves:** *Grammatodon* sp. [1], '*Brachidontes*' *somalicus* Cox [9], *Modiolus* cf. *bipartitus* J. Sowerby [1], *Eligmus* sp. [1], *Spondylopecten* cf. *subpunctatus* (Münster) [1], *Eopecten* cf. *aubreyi* (Douvillé) [1], *Plagiostoma ?harronis* Dacqué [1], ?'*Gryphaea*' *balli* (Stefanini) [1], *Actinostreon solitaria* (J. Sowerby) [1], ?*Neocrassina* sp. [1], *Procyprina hunti* (Cox) [2], ?*Eocallista krenkeli* Cox [1], *Ceratomyopsis somaliensis* (Weir) [16], ?*Tellurimya* ?sp. nov. [1], *Pholadomya ?ovalis* (J. Sowerby) [1], *Bucardiomya somaliensis* (Cox) [3], *Bucardiomya aubreyi* (Douvillé) [4], *Ceratomya* cf. *pittieri* (de Loriol) [2], *C.* cf. *wimmisensis* (Gilliéron) [1]. **Gastropods:** *Ampullospira* sp. [1], *Nerinella* sp. [4].

Lower Shuqra:

Near base. Gastropods: *Nerinella* sp. [7].

Loose. Brachiopods: *Conarosia rotundata* Cooper [4], *Daghanirhynchia sulcata* Cooper [18], *Bihenithyris* cf. *bihenensis* Muir-Wood [12], ?'*Stiphrothyris*' sp. [2]. **Echinoid:** *Bothriopygus somaliensis* (Currie) [1]. **Stromatoporoid:** *Shuqraia* sp. [5]. **Corals** [4]. **Bivalves:** *Plagiostoma ?harronis* Dacqué [1], *Actinostreon solitaria* (J. Sowerby) [2], '*Lucina*' sp. [5], ?*Mactromya* sp. [1], ?*Tendagurium* sp. [5], *Bucardiomya* cf. *lyrata* (J. Sowerby) [2], *Homomya* cf. *gibbosa* (J. Sowerby) [3], *Ceratomya* cf. *pittieri* (de Loriol) [1], ?*Colpomya* sp. [1]. **Gastropods:** *Ampullospira* sp. [3], ?*Nerinella* sp. [4].

Central Jebel Billum (south of main Jurassic cliff) (N14°19'00" E48°26'48")

Madbi Formation:

104.5 m above base (7.3 m below top). Bivalves: *Indogrammatodon egertonianus* (Stoliczka) [4], *Modiolus* cf. *bipartitus* J. Sowerby [2], *Nannogyra fourtaui* (Stefanini) [4], *Trigonia* sp. [1].

87 m above base. Brachiopods: *Somalirhynchia africana* Weir [6], *Somalithyris bihendulensis* Muir-Wood [4], *Somalithyris* cf. *somaliensis* Weir [2]. **Bivalves:** *Indogrammatodon egertonianus* (Stoliczka) sp. [3], *Nannogyra fourtaui* (Stefanini) [20], ?*Actinostreon* sp. [1], *Trigonia* sp. [1].

65.3–67.4 m above base. Brachiopods: *Microthyridina farquharsoni* Muir-Wood [14]. **Bivalves:** *Camptonectes* sp., ?*Trigonia* sp., ?*Neocrassina* sp. [1].

Upper Storm Bed, 46–48 m above base. Brachiopods: *Somalirhynchia arabica* Cooper [7], *Bihenithyris* sp. [6], *Microthyridina farquharsoni* Muir-Wood [22]. **Bivalves:** *Indogrammatodon egertonianus* (Stoliczka) [5], *Modiolus* cf. *bipartitus* J. Sowerby [2], '*Posidonia*' *somaliensis* Cox [few], *Eopecten* sp., ?*Plagiostoma* sp. [few], *Deltoideum delta* (Smith) [18], *Nannogyra fourtaui* (Stefanini) [40], *Actinostreon* aff. *solitaria* (J. Sowerby) [3].

32–42 m above base. Brachiopods: *Somalirhynchia africana* var. *smelliei* Weir [8], *S.* cf. *arabica* Cooper [6], *Somalirhynchia* sp. [1], *Avonothyris* sp. [12], *Bihenithyris* sp. [11], *Cerethyris* sp., [fragments, few], *Mycerosia ?amygdaliformis* Cooper [3], *Ptyctothyris daghanensis* Muir-Wood [1]. **Bivalves:** '*Posidonia*' *somaliensis* Cox [1], *Deltoideum delta* (Smith) [1], *Trigonia* sp. [1], *Colpomya* sp. [1].

Lower Storm Bed, at base of formation. Ammonite: *Laevaptychus* [1]. **Brachiopods:** *Somalirhynchia africana* var. *smelliei* Weir [4], *S.* cf. *africana* Weir [20], *S.* cf. *arabica* Cooper [38], *Somalirhynchia* sp. (large, coarsely costate) [2], *Bihenithyris weiri* Muir-Wood [2], *Cererithyris* cf. *wyvillei* (Weir) [4], *Ptyctothyris daghaniensis* Muir-Wood [8], ?*Rugetela* sp. [2 fragments]. **Bivalves:** *Palaeonucula* sp. [2], *Indogrammatodon egertonianus* (Stoliczka) [26], '*Posidonia*' *somaliensis* Cox [31], *Camptonectes* sp. [2], *Nannogyra fourtaui* (Stefanini) [72], *Actinostreon* aff. *solitaria* (J. Sowerby) [2], *Trigonia* sp. [1], *Neocrassina* aff. *unilateralis* (J. de C. Sowerby) [4]. **Gastropods:** *Proconulus arabiensis* (Newton) [17].

Shuqra Formation:
Upper Shuqra:

1 m below top. Bivalves: ?*Procyprina* sp. [20].

7–10 m below top. Brachiopods: *Somalirhynchia* fragments [15]. **Echinoids:** *Acrosalenia (Recrosalenia) somaliensis* Currie [3], ?*Plegiocidaris* sp. [1]. **Crinoids:** ?*Angulocrinus* sp. [2], ?*Millericrinus* sp. [2]. **Bivalves:** *Nannogyra fourtaui* (Stefanini) [10], *Actinostreon solitaria* (J. Sowerby) [3].

17 m below top, rubbly marls and nodular limestones. Ammonite: *Erymnoceras (Pacherymnoceras) jarryi* (Douvillé) [1].

Brachiopods: *Somalirhynchia africana* Weir [13], Terebratulidae indet. [2]. **Bivalves:** *'Brachidontes' somalicus* Cox [5], *Modiolus* cf. *bipartitus* J. Sowerby [2], *Eligmus humei* (Stefanini) [8], *Entolium* sp. [1], *Eopecten* cf. *aubreyi* (Douvillé) [1], *Plagiostoma ?harronis* Dacqué [4], *'Gryphaea' balli* sp. [1], *Nannogyra fourtaui* (Stefanini) [1], *Mactromya* sp. [2], *Tendagurium* cf. *propebanneiana* (Dietrich) [2], *Procyprina hunti* (Cox) [4], *Ceratomyopsis somaliensis* (Weir) [3], *Bucardiomya somaliensis* (Cox) [1], *Ceratomya* cf. *pittieri* (de Loriol) [2]. **Gastropods:** *Rhabdoconcha* sp. [1], *Ampullospira* sp. [2], *'Bulla'* sp. [1].

21–23 m below top (0–2 m above Nautiloid Bed), *Eligmus aualites* horizon. Brachiopods: *Somaliryhnchia* cf. *arabica* Cooper [16], *Bihenithyris* sp. [5]. **Echinoid:** *Acrosalenia (Recrosalenia) somaliensis* Currie [4]. **Crinoid:** *?Angulocrinus* sp. [1]. **Bivalves:** *?Palaeonucula* sp. [1], *'Brachidontes' somalicus* Cox [3], *Eligmus aualites* (Stefanini) [50+], *Eligmus* sp. [2], *?'Gryphaea' balli* (Stefanini) [8], *Nannogyra fourtaui* (Stefanini) [5], *Actinostreon solitaria* (J. Sowerby) [11], *Arctostrea eruca* (Lamarck) [1], *Mactromya* sp. [2], *Procyprina hunti* (Cox) [4], *?Eocallista krenkeli* Cox [5], *Ceratomyopsis somaliensis* (Weir) [5], *Tellurimya* ?sp. nov. [1], *Ceratomya* cf. *pittieri* (de Loriol) [1]. **Gastropods:** *?Pietteia* sp. [1].

23 m below top, limestone, 0.5 m thick, the Nautiloid Bed. Nautiloids: *Paracenoceras meridionale* Tintant [5], *P. calloviense* (Oppel) [1].

23–26 m below top (incl. Nautiloid Bed). Brachiopods: *Conarosia* sp. [15], *Somalirhynchia arabica* Cooper [9], *Bihenithyris barringtoni* Muir-Wood [1], *B. weiri* Muir-Wood [4]. **Bivalves:** *Parallelodon* sp. [1], *'Brachidontes' somalicus* Cox [27], *Modiolus* cf. *bipartitus* J. Sowerby [1], *Eligmus aualites* (Stefanini) [4], *E. humei* (Stefanini) [2], *Plagiostoma ?harronis* Dacqué [1], *Plagiostoma* sp. [1], *'Gryphaea' balli* (Stefanini) [6], *Nannogyra fourtaui* (Stefanini) [4], *Actinostreon solitaria* (J. Sowerby) [6], *Myoconcha* sp. [1], *Tendagurium* cf. *propebanneiana* (Dietrich) [3], *Procyprina hunti* (Cox) [15], *?Eocallista krenkeli* Cox [2], *Ceratomyopsis arabica* (Cox) [6], *Bucardiomya somaliensis* (Cox) [2], *Ceratomya* cf. *pittieri* (de Loriol) [2], *Ceratomya* cf. *wimmisensis* (Gilliéron) [1]. **Gastropods:** *Rhabdoconcha* sp. [3], *Ampullospira* sp. [2].

27–30 m below top. Brachiopods: *Somalirhynchia* cf. *africana* Weir [12], *Somalirhynchia* sp. [4], *Arabicella arabis* Cooper [1], *A. ovalis* Cooper [5], *Arapsopleurum* cf. *arabicum* Cooper [2], *A. rotundum* Cooper [8], *Arapsothyris angusta* Cooper [1], *?'Stiphrothyris'* sp. [1]. **Bivalves:** *Parallelodon* sp. [2], *'Brachidontes' somalicus* Cox [10], *?Modiolus* cf. *bipartitus* (J. Sowerby) [1], *Stegoconcha* sp. [few], *Trichites* sp. [few], *?Pteroperna* sp. [1], *Eligmus aualites* (Stefanini) [2], *E. humei* (Stefanini) [2], *Spondylopecten* cf. *subpunctatus* (Münster) [2], *Eopecten* cf. *aubreyi* (Douvillé) [1], *Plagiostoma* sp., *'Gryphaea' balli* (Stefanini) [1], *Nannogyra fourtaui* (Stefanini) [1], *?Actinostreon* sp. [1], *Trigonia* sp. [1], *Procyprina hunti* (Cox) [4], *Ceratomyopsis somaliensis* (Weir) [5], *Bucardiomya somaliensis* (Cox) [4], *B. aubreyi* (Douvillé) [1], *Ceratomya* cf. *wimmisensis* (de Loriol) [3]. **Gastropods:** *Ampullospira* sp. [4], *?Nerinella* sp. [3].

38.5–45.5 m below top. Brachiopods: *Conarosia* sp. [33], *Daghanirhynchia* sp. [4], *Somalirhynchia africana* Weir [12], *S. arabica* Cooper [4], *S. somalica* (Dacqué) [2], *Somalirhynchia* sp. nov. [31], *Bihenithyris barringtoni* Muir-Wood [12], *B. weiri* Muir-Wood [3], *Cererithyris* cf. *wyvillei* (Weir) [40], *Ptyctothyris daghaniensis* Muir-Wood [3], *'Terebratula' aulites* Stefanini [1]. **Echinoids:** *Acrosalenia (Recrosalenia) somaliensis* Currie [5]. **Bivalves:** *Parallelodon* sp. [2], *'Brachidontes' somalicus* Cox [4], *Modiolus* cf. *bipartitus* (J. Sowerby) [8], *Eligmus humei* (Stefanini) [3], *E.* cf. *weiri* Cox [2], *Spondylopecten* cf. *subpunctatus* (Münster) [2], *'Gryphaea' balli* (Stefanini) [3], *?Nannogyra fourtaui* (Stefanini), *Actinostreon solitaria* (J. Sowerby) [4], *Trigonia* sp. [1], *Myoconcha* sp. [1], *Tendagurium* cf. *propebanneiana* (Dietrich) [1], *Procyprina hunti* (Cox) [17], *?Eocallista krenkeli* Cox [2], *Ceratomyopsis somaliensis* (Weir) [5], *Bucardiomya aubreyi* (Douvillé) [1], *B. somaliensis* (Cox) [4], *Ceratomya* cf. *wimmisensis* (de Loriol) [1]. **Gastropods:** *Rhabdoconcha* sp. [1], *Ampullospira* sp. [8].

Loose, lower part. Bivalves: *Eligmus humei* (Stefanini) [3], *E. aualites* Stefanini [1], *Ceratomya* sp. [2], *Pholadomya aubreyi* (Douvillé). **Gastropods:** *'Natica'* sp. [1], *Rhabdoconcha* sp. [1].

Middle Shuqra:

Top 3 m. Brachiopods: *Somalirhynchia* cf. *arabica* Cooper [18], *S. somalica* (Dacqué) [1], *Bihenithryis* cf. *barringtoni* Muir-Wood [1], *Cererithyris* sp. [16], *Ornithella* sp. [1]. **Bivalves:** *Palaeonucula* sp. [1], *'Brachidontes' somalicus* Cox [6], *Modiolus* cf. *imbricatus* J. Sowerby [5], *Eligmus* sp. [6], *Spondylopecten* cf. *subpunctatus* (Münster) [5], *Eopecten* cf. *aubreyi* (Douvillé) [1], *Plagiostoma* sp. [1], *Actinostreon solitaria* (J. Sowerby) [6], *Trigonia* sp. [2], *'Lucina'* sp. [1], *?Tendagurium* sp. [1], *Procyprina hunti* (Cox) [2], *Pseudotrapezium* sp. of Cox [1], *Ceratomyopsis somaliensis* (Weir) [12], *Tellurimya* ?sp. nov. [1], *Bucardiomya somaliensis* (Cox) [3], *Bucardiomya aubreyi* (Douvillé) [4], *Ceratomya* cf. *wimmisensis* (de Loriol) [4], *?Plectomya* sp. [5]. **Gastropods:** *Discohelix* sp. [1], *Ampullospira* sp. [9], *?Nerinella* sp. [many], *Cylindrobullina* sp. [1].

Lower part. Bivalves: *Pseudotrapezium* sp. of Cox [1], *?Eocallista krenkeli* Cox [1]. **Gastropod**: *?Nerinella* sp. [1].

A slumped section of the Upper Shuqra was also examined 1 km to the east, below the main cliff:

Above *Eligmus aualites* horizon. Brachiopods: *Somalirhynchia* cf. *arabica* Cooper [108], *Apatecosia* sp. [7], *Arabicella* sp. [ca.20], *?Arapsopleurum* sp. [ca.15], *Bihenithyris* cf. *quadrilobata* Cooper [5], *B. weiri* Muir-Wood [2], *Cererithyris* sp. [ca.20], *Somalithyris macfadyeni* Muir-Wood [3]. **Bivalves:** *'Brachidontes' somalicus* Cox [7], *Lithophaga* sp., *Modiolus* cf. *bipartitus* J. Sowerby [3], *Eligmus humei* (Stefanini) [29], *E. aualites* (Stefanini) [3], *Spondylopecten* cf. *subpunctatus* (Münster) [1], *Eopecten* cf. *aubreyi* (Douvillé) [1], *Plagiostoma* sp. [1], *'Gryphaea' balli* (Stefanini) [14], *Deltoideum delta* (Smith) [1], *Nannogyra fourtaui* (Stefanini) [6], *Actinostreon solitaria* (J. Sowerby) [36], *Myoconcha* sp. [1], *Tendagurium* cf. *propebanneiana* (Dietrich) [1], *Procyprina hunti* (Cox) [7], *Pseudotrapezium* sp. of Cox [1], *Ceratomyopsis somaliensis* (Weir) [5], *Bucardiomya somaliensis* (Cox) [5], *Ceratomya* cf. *wimmisensis* (Gilliéron) [3], *?Pleuromya* sp. [1]. **Gastropods:** *Ampullospira* sp. [9], *?Bourguetia* sp. [1].

***Eligmus aualites* horizon. Brachiopods:** *Conarosia* sp. [10], *Somaliryhnchia* cf. *arabica* Cooper [68], *Cererithyris* sp. [25], *?Dissoria obscura* Cooper [3], *Somalithyris macfadyeni* Muir-Wood [30]. **Bivalves:** *Palaeonucula* sp. [1], *'Brachidontes' somalicus* Cox [8], *Modiolus* cf. *bipartitus* J. Sowerby [1], *Eligmus aualites* (Stefanini) [30+], *E. humei* (Stefanini) [1], *Limaria* sp. [2], *'Gryphaea' balli* (Stefanini) [3], *Nannogyra fourtaui* (Stefanini) [7], *Actinostreon solitaria* (J. Sowerby) [10], *?Sphaera* sp. [1], *Procyprina hunti* (Cox) [7], *?Eocallista krenkeli* Cox [6], *Tellurimya* ?sp. nov. [1], *Bucardiomya somaliensis* (Cox) [1]. **Gastropods:** *Ampullospira* sp. [6].

Jebel Billum, western entrance road cutting (N14°18'48" E48°25'53")

Naifa Formation, Billum Member:

Argillaceous limestone, ca. 20 m above base. Ammonites: *Glochiceras (G.) subclausum* (Oppel) [5]; *Orthosphinctes polygyratus* (Reinecke) [1]. **Bivalves:** *Indogrammatodon egertonianus* (Stoliczka) [3], *Nannogyra fourtaui* (Stefanini) [many].

Limestone, in basal 5m. Ammonite: *Paryphoceras grayi* (Spath) [1].

Wadi Arus, road gorge leading into southern end of Wadi

Hajar Formation, Mintaq Member:

Limestone, 16 m below Qishn Formation. Ammonite: *Aspidoceras* sp. indet. (photograph of 0.5 m diameter specimen).

Flaggy limestone, 31.5 m below Qishn Formation. Ammonites: *Substeueroceras striatus* sp. nov. [27]; *Protacanthodiscus*. sp. indet. [4].

Wadi Arus, cliffs on east and west sides

Hajar Formation, Arus Member:

Microbialite boulders in basal 7m. Ammonites: *Pseudoclambites araense* sp. nov. [18], *Baeticoceras morrisi* sp. nov. [2], *Virgatosimoceras broilii* (Schneid) [1], *Aulacosphinctes spitiensis* (Uhlig) [1], *Aulacosphinctes natricoides* (Uhlig) [2], *Micracanthoceras fraudator* (Zittel) [1], *Himalayites* sp. indet. [1], *Spiticeras gregoryi* (Spath) [1], *Virgatosphinctes* cf. *broilii* (Uhlig) [1], *Berriasella (B.)* cf. *oxycostata* Mazenot [7], *Riasanites rjasanensis* (Lahusen) [2], *Blanfordiceras wallichi* (Gray) [1]. **Echinoid:** *Collyrites* cf. *loryi* (Gras) [1].

Wadi Arus, cliff on east side (N14°20'17" E48°23'34")

Naifa Formation, Kilya Member:

Astarte Bed, 0.3 m below top. Bivalves: *Neocrassina spitiensis* (Stoliczka [sensu Holdhaus]) [40].

Breadloaf Concretions, in marls 15–20 m above lowest exposure. Ammonites: *Taramelliceras (T.) pseudoflexuosum* (Favre) [2], *Taramelliceras (T.)* cf. *insistens* Hölder [4], *Haploceras staszycii* (Zejszner) [8], *Glochiceras (Lingulaticeras) pseudocarachteis* (Favre) [4], *Torquatisphinctes naifaensis* sp. nov. [1], *Sutneria weidmanni* Zeiss [7], *Pachysphinctes bathyplocus* (Waagen) [5], *Pachysphinctes major* Spath [5], *Idoceras ahwarense* sp. nov. [1], *Idoceras* cf. *balderum* (Oppel) [1], *Nebrodites hospes* (Neumayr) [1], *Simaspidoceras argobbae* (Dacqué) [8], *Laevaptychus* [6], *Lithacoceras (Subplanites) mombassanum* (Dacqué) [2], *Lithacoceras* sp. indet. [1]. **Bivalves:** *Parainoceramus* sp. [2], *Aulacomyella farquharsoni* Cox [15], *'Posidonia' somaliensis* Cox [many], *Liostrea* cf. *boloniensis* de Loriol [1].

Wadi Arus, cliff on west side (N14°20'29" E48°23'30")

Naifa Formation, Billum Member:

Top bed of limestone forming pavement at base of cliff. Ammonites: *Streblites plicodiscus* (Waagen) [4 photographs]; indet. perisphinctids (*?Torquatisphinctes*) [6 photographs]. **Bivalves:** *Parainoceramus* sp. [few].

Mintaq Salt Dome; southwestern exposure leading up to contact with Qishn Formation (N14°33'09" E48°02'35")

Qishn Formation:

73 m above base, *Orbitolina* Limestone. Echinoid: *Leptosalenia somaliensis* Hawkins [2]. **Bivalves:** *Amphidonte* sp. [2], *Pholadomya valangiensis* Pictet & Campiche [1]. **Gastropod:** *?Pseudomelania* sp. [1].

38–46 m above base, Lower Oyster Beds. Bivalves: *Lithophaga* sp., *'Exogyra'* cf. *tuberculifera* Koch & Dunker [many], *Trigonia* sp. [1], *Syriotrigonia picteti* (Coquand) [1], *Opis* sp. [1], *?Tendagurium* sp. [1]. **Gastropods:** *?Nerinella* sp. [6], *Procerithium* sp. [1].

Hajar Formation, Mintaq Member (metres above base in brackets are above the contact with the Sabatayn Formation):

Bed 149 (8.5 m limestones and marls; 150.0 m above base), 0.75 m above base. Ammonites: *?Protacanthodiscus* or *Neocosmoceras* spp. indet. [1]; *?Neocomites* sp. indet. [1].

Bed 96 (0.3 m limestone; 113.35 m above base). Ammonites: *Dalmasiceras* sp. indet. [2].

Bed 77 (0.2 m limestone with haemetite; 103.85 m above base). Ammonites: *Spiticeras (S.) pricei* sp. nov. [1].

Bed 75 (0.3 m brown limestone; 103.45 m above base). Ammonites: *Spiticeras (S.) pricei* sp. nov. [4]; *Berriasella* sp. indet. [1].

Bed 69 (0.2 m brown limestone; 101.55 m above base). Ammonites: *Haploceras umbilicatum* sp. nov. [1], *Spiticeras (S.) pricei* sp. nov. [6], *Spiticeras subspitiense* (Uhlig) [1], indet. berriasellid [1].

Bed 64 (0.5 m brown, fine-grained limestone nodules; 99.55 m above base). Ammonite: *Argentiniceras mintaqi* sp. nov. [1].

Bed 60 (0.35 m fine-grained brown limestone with abundant haemetite nodules; 98.0 m above base). Ammonites: *Aspidoceras* cf. *taverai* Checa [2], *Spiticeras (S.) pricei* sp. nov. [41], *Spiticeras* sp. indet. [1], *Berriasella (Elenaella) sevenieri* (Le Hégarat) [1], *Berriasella (Picteticeras) chomeracensis* (Toucas) [1], *Berriasella* spp. indet. [6], *Substeueroceras koeneni* (Steuer) [1], *Argentiniceras mintaqi* sp. nov. [1].

Bed 57 (0.3 m limestone; 97.2 m above base). Ammonites: *Haploceras umbilicatum* sp. nov. [2], *Aspidoceras* cf. *taverai* Checa [1], *Argentiniceras mintaqi* sp. nov. [2], *Argentiniceras mutatum* (Steuer) [1], *Spiticeras* sp. indet. [1]. **Echinoid:** *Collyrites* cf. *loryi* (Gras) [2].

Bed 36 (0.2 m brown limestone; 90.4 m above base). Ammonites: *Aspidoceras rogoznicense* (Zejszner) with *Laevaptychus* attached [2], *Spiticeras (S.) pricei* sp. nov. [4], *Spiticeras (S.)* sp. (thick, quadrate whorls) [1], *Spiticeras (S.)* sp. (compressed whorls, involute) [1], *Spiticeras (Negreliceras) obliquenodosum* (Retowski) [1], *Berriasella (Elenaella) sevenieri* (Le Hégarat) [1], *Malbosiceras* sp. indet. [1], Berriasellid s.l., microconch or deformed [1], *Argentiniceras mintaqi* sp. nov. [1], *Neocosmoceras* sp. indet. [1]

Bed 34 (0.3 m grey-brown limestone; 90.0 m above base). Ammonites: *Spiticeras (S.) subspitiense* (Uhlig) [1]; *Spiticeras (S.) pricei* sp. nov. [1].

Bed 31 (1.2 m brown, marly, rubbly limestone; 87.9 m above base): *Spiticeras (S.) spitiense* (Blanford) [1], *Spiticeras (S.) indicum* (Uhlig) [2], *Spiticeras (Negreliceras) paranegreli* Djanélidzé [1], Indet ?Spiticeratinid [1].

Bed 30 (0.3 m grey-brown, marly, nodular limestone; 87.6 m above base). Ammonites: *Aspidoceras* cf. *taverai* Checa [1]; *Laevaptychus* [6]; *Spiticeras pricei* sp. nov. [2]; *Spiticeras (Negreliceras)* cf. *obliquenodosum* (Retowski) [1]; indet. berriasellid [1].

Bed 29 (0.8 m brown, marly limestone; 86.8 m above base). Ammonites: *Spiticeras pricei* sp. nov. [1], *Spiticeras (Negreliceras) obliquenodosum* (Retowski) [1], *Laevaptychus* [5], *Berriasella (Picteticeras) chomeracensis* (Toucas) [1], *Berriasella* spp. indet. [1].

Bed 27 (1.3 m Grey-brown, fine-grained limestone; 85.1 m above base). Ammonites: *Spiticeras (S.) pricei* sp. nov. [3].

Bed 21 (0.4 m grey-brown, fine-grained limestone; 81.0 m above base). Ammonites: indet. ?berriasellids [3].

Bed 13 (0.3 m thinly laminated limestone; 60.7 m above base). Ammonites: indet. ?berriasellid [1].

Bed 3 (3.8 m grey, fine-grained, thin-bedded limestones, with marly partings; 27.5 m above base), 1 m above base. Ammonite: ?*Dalmasiceras* sp. indet. [1].

Bed 1 (25 m buff-grey, fine-grained limestones in beds 0.2–0.7 m thick), 0.4 m below top. Ammonite: *Substeueroceras striatum* sp. nov. [1].

Jebel Madbi (N14°21'20" E48°01')

Hajar Formation, Mintaq Member:

In upper part of member, on summit of Jebel Madbi. Ammonite: *Tirvonella occitanica* (Pictet) [2].

NOTE ADDED IN PROOF

After this paper had gone to print, a paper was published by Beydoun (1997, Introduction to the revised Mesozoic stratigraphy and nomenclature for Yemen, *Marine and Petroleum Geology*, **14** (6): 617–629) which made many revisions to the lithostratigraphical nomenclature of the Jurassic of Yemen. These are to be formalized in a new edition of the Yemen volume of the *Lexique Stratigraphique International (Paris)*, scheduled for publication in 1997, but which we have not seen.

The most far-reaching change is to the Upper Oxfordian to lowest Tithonian Naifa Formation, whose type locality is at Naifa Cliff, Ma'abir. Beydoun proposed to alter the type locality to the Mintaq Salt Dome, 65km to the north-west, where the rocks are Upper Tithonian and Berriasian in age. This is to be done because of past mis-correlation and misinterpretation of the age. However, such wholesale alteration of the type section of a formation is not permitted under Article 22 (c) of the North American Stratigraphic Code (NASC) which maintains:

'**Type section never changed**. – The definition and name of a stratigraphic unit are established at a type section (or locality) that, once specified, must not be changed' (NASC, 1983, *Bulletin American Association Petroleum Geologists*, **67:** 856).

We fully support the NASC's aim of achieving reasonable stability in lithostratigraphical nomenclature. In advancing such stability for the Jurassic rocks of Wadi Hajar and Yemen, we would make the following points:

1. An important purpose of lithostratigraphical nomenclature at Formation level is to name rocks units that are lithologically distinct, and are easily separable on the ground as mappable units. In Wadi Hajar the formations we use have widely different lithologies, and are based on those originally proposed by Beydoun (1964). Thus the Kohlan, Shuqra, Madbi, Naifa and Hajar Formations consist of markedly different arenaceous, calcareous, argillaceous, calcareous and calcareous rocks respectively, the latter two being separated by an unconformity and by detailed lithological differences. Such clear division of the Jurassic is abandoned by Beydoun's new proposals.
2. The Madbi Formation is argillaceous at its type locality on Jebel Madbi, and the term was used for the same rock division in Wadi Hajar by Beydoun (1964). Its extension upwards to include the heavily calcareous 'Madbi Porcellanites' (= our Billum Member; = Ma'abir Member newly proposed by Beydoun), then a calcareous 'Upper Madbi Shales' (= our Kilya Member) places widely differing lithologies in the Madbi Formation. The overlying Billum Member makes such a marked contrast to the argillaceous Madbi Formation that it needs a different formation name, for which Naifa Formation is available, as originally defined with its type locality at Naifa Cliff, near Ma'abir. Billum Member (or Ma'abir Member if this is held to have priority) is the name for the heavily calcified lower half, and Kilya Member for the calcareous upper half. A 'Madbi Formation' for all the rocks from the bottom of the Madbi to the top of the Naifa Formation as used by us, embraces too many markedly different lithologies, over too large an age range from the bottom of the Oxfordian to the bottom zone of the Tithonian.
3. Beydoun (1964) was already in possession of ammonite evidence that the date of the Naifa Formation at its type locality was Upper Oxfordian/Lower Kimmeridgian, and collections of ammonites giving good dating evidence can be obtained in abundance in Wadi Hajar, as the present paper shows. Miscorrelation from Naifa Cliff to Wadi Arus then Mintaq (where microfossil evidence showed that the date of the wrongly identified 'Naifa' Formation was Upper Tithonian/Berriasian) cannot be used as a reason for the illegal alteration of the type locality of the Naifa Formation.
4. Nor is the subsequent misuse of the term 'Naifa Formation' (many in unpublished company reports) sufficient reason to alter its type locality and age to the Mintaq Salt Dome and Upper Tithonian to Berriasian. The rocks at Mintaq are similar in lithology to those of the Naifa Formation at Naifa Cliff, but they are wholly different in age and are separated from the latter by an unconformity and intermediate beds (our Arus Member) that are lithologically different. Our new division, the Mintaq Member, Hajar Formation, is available for the Mintaq rocks.
5. For reasons of priority, clear lithological differentiation and inviolability of the type section, Beydoun's original nomenclature and usage, as interpreted and refined with age dating in our paper, should be retained in preference to the extension of the Madbi Formation upwards to include rocks of entirely different lithology, and the alteration of the age and type locality of the Naifa Formation. The subsurface data now available from many parts of Yemen does not invalidate the lithostratigraphical nomenclature used for Wadi Hajar. If rocks of different lithology and/or intermediate age are present in the subsurface, they can be given new formation names applicable to the local conditions. It seems, however, that age dating for the subsurface rocks may not be known in sufficient detail to make good comparisons with the rocks in Wadi Hajar.

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Ammonites and nautiloids from the Jurassic and Lower Cretaceous of Wadi Hajar, southern Yemen

MICHAEL K. HOWARTH

Department of Palaeontology, The Natural History Museum, Cromwell Road, London SW7 5BD

CONTENTS

Synopsis. Middle Callovian to Upper Aptian ammonites described mainly from Wadi Hajar and Jebel Madbi, southern Yemen, include: Middle Callovian, Coronatum Zone, *Erymoceras* from the Shuqra Formation; Oxfordian perisphinctids in the Madbi Formation; Upper Oxfordian, Bimammatum Zone, *Orthosphinctes, Larcheria, Paryphoceras* and *Epimayaites* low in the Billum Member, Naifa Formation; a Lower Kimmeridgian, Divisum Zone, *Crussoliceras* in the upper half, and Upper Kimmeridgian, Eudoxus/Beckeri Zone, *Streblites* and ?*Torquatisphinctes* at the top of the Billum Member; Upper Kimmeridgian, Beckeri Zone, *Taramelliceras, Sutneria, Idoceras, Aspidoceras, Simaspidoceras, Lithacoceras, Pachysphinctes, Torquatisphinctes naifaensis* and *Idoceras ahwarense* spp. nov, from the lower and middle parts of the Kilya Member, Naifa Formation, and additionally Lower Tithonian, Hybonotum Zone, *Katroliceras, Subdichotomoceras* and *Hybonoticeras* from the upper part; Upper Tithonian, Microcanthum Zone, *Aulacosphinctes, Micracanthoceras, Spiticeras, Berriasella, Blanfordiceras, Riasanites rjasanensis, Pseudoclambites araense* and *Baeticoceras morrisi* spp. nov. from the Arus Member, Hajar Formation; Upper Tithonian, Durangites Zone, *Virgatosphinctes, Choicensisphinctes, Berriasella, Substeueroceras* and *Malbosiceras*, higher in the Arus Member and low in the Mintaq Member, Hajar Formation; *Substeueroceras striatum* sp. nov. higher in the Mintaq Member; Berriasian, Occitanica Zone, *Aspidoceras, Berriasella, Tirnovella, Spiticeras, S. pricei, Haploceras umbilicatum* and *Argentiniceras mintaqi* spp. nov., from the middle part of the Mintaq Member; a single Upper Hauterivian *Crioceratites* low in the Qishn Formation; and Upper Aptian *Cheloniceras* from the upper half of the Qishn Formation.

INTRODUCTION

The ammonites and nautiloids described here come from localities and sequences in Wadi Hajar that are descibed in detail in the preceding paper in this *Bulletin* (Howarth & Morris, 1998). They range in age from the middle of the Callovian to the Upper Aptian, and come from all the formations that make up the Jurassic and the lower part of the Cretaceous in Wadi Hajar, except for the lowest, the arenaceous Kohlan Formation, which overlies the Precambrian basement and contains no fossils. From Callovian to Hauterivian, most horizons are represented, except for two major disconformities, the first missing out the whole of the Lower Tithonian except for part of the basal Hybonotum Zone, and the second excluding the upper part of the Berriasian, the Valanginian and Lower Hauterivian.

About 710 of the specimens were collected by the author and Dr Noel Morris during two visits to Wadi Hajar in November 1991 and January 1994. To these were added about 20 ammonites from that area given to us by Dr John Smewing, and 79 ammonites collected by Z.R. Beydoun and E.K. Elliott in the mid-1950s, 70 of which are in the Sedgwick Museum, Cambridge, and 9 in the Natural History Museum. That makes a total of 809 ammonites examined for this paper. Many of those from the Upper Kimmeridgian and Tithonian are well-preserved, some exceptionally so, while the Callovian and Oxfordian ammonites are crushed and fragmentary, but regretably many of the topmost Tithonian and Berriasian ammonites are not as well preserved as might be hoped for, given their considerable interest.

The ammonites collected by Beydoun and Elliott were identified by Spath and Arkell and listed in Beydoun's (1964) description of the Wadi Hajar area, but none were described or figured. They formed the basis of some of Beydoun's age assessments of the formations in that area, which were used as a starting point for the new work described here.

Few other ammonites have been described and figured from any part of Yemen. From Wadi Hajar itself, three fragments of Upper Kimmeridgian *Pachysphinctes* and ?*Lithacoceras* were figured by Stefanini (1925: 142–48, pl. 27, figs 1–3), that were the result of Little's (1925) pioneering geological exploration up Wadi Hajar in 1920. These can now be identified as coming from the middle part of the Kilya Member, Naifa Formation, at Naifa Cliff, the type locality of the Naifa Formation. Earlier, Crick (1908: 11–24, pl. 2, figs 2, 3, pl. 3, figs 1–4) had described five perisphinctids, one oppelid and two nautiloids (?*Paracenoceras*) from near Dihala, about 150 km north of Aden. They are in the collections of the Natural History Museum, but are too poor for more accurate identification, though it is likely that the perisphinctids are of (?Upper) Kimmeridgian age and from rocks that would now be referred to the Naifa Formation or its equivalent in that area. Finally, Tipper (1910: 338, pl. 35, figs 1, 2, pl. 36, figs 1, 2) described some perisphinctids from a limestone in the same area north of Aden, which are also poorly preserved, though *Pachysphinctes* is a possible determination for two of them (pl. 35, figs 1, 2), and they might also be Upper Kimmeridgian in age. No other ammonites have been described from Yemen.

The Jurassic and Lower Cretaceous ammonite zones and the lithological formations from which the Wadi Hajar ammonites were collected are shown in Table 1. The ammonite faunas described belong to the 14 biostratigraphical horizons indicated by asterisks in that Table, the age evidence for which is discussed in the final part of the present paper.

SYTEMATIC DESCRIPTIONS

Specimen register numbers with the prefixes CA or C. (ammonites) and CN (nautiloids) are in the collections of The Natural History

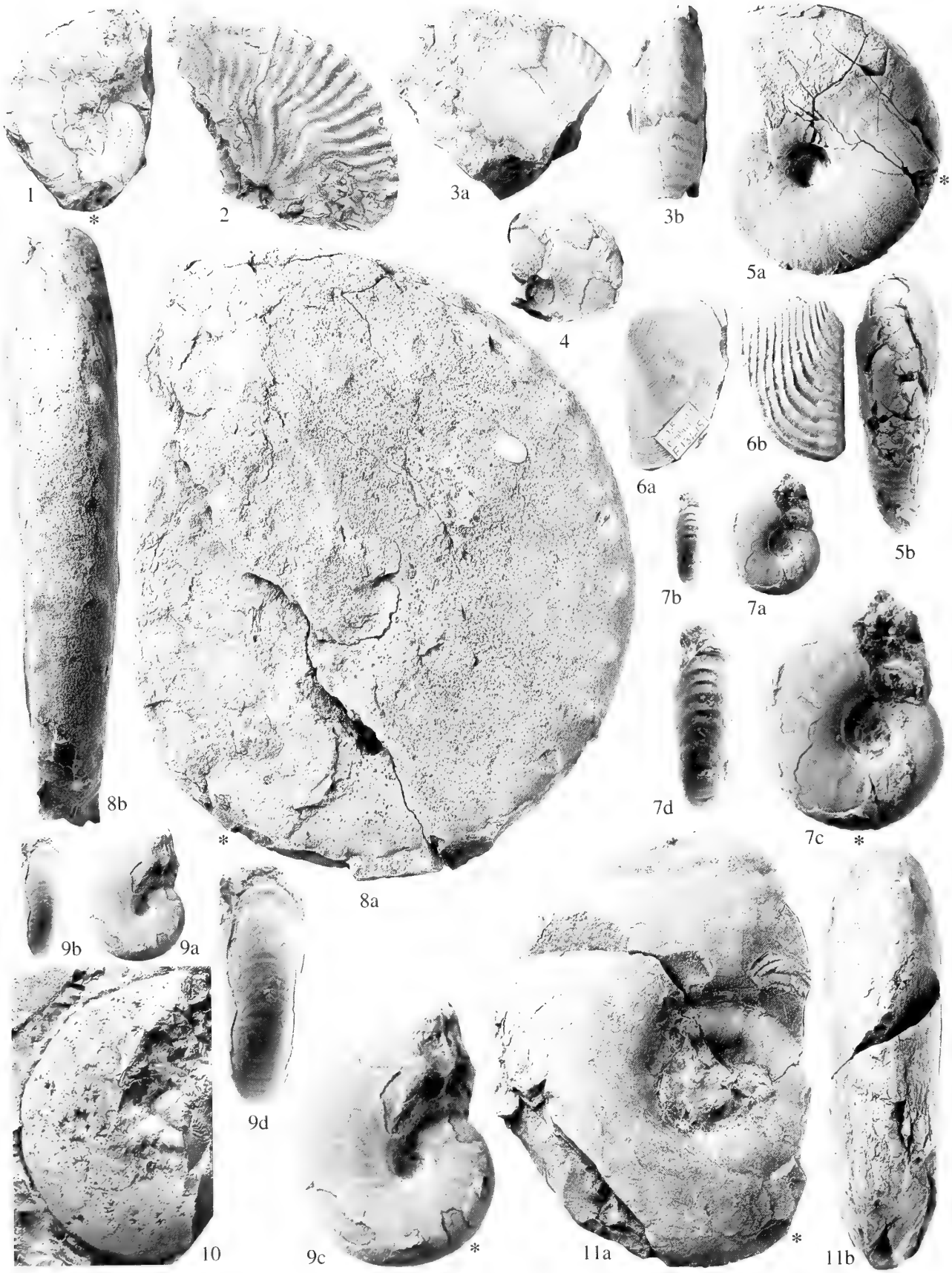
Table 1 Ammonite zones of the Callovian to Berriasian Stages and the dates of the formations in Wadi Hajar. The zones in the Callovian and Lower and Middle Oxfordian are the Euroboreal primary zones, while those in the Upper Oxfordian to Berriasian are the Submediterranean standard zones that are appropriate to the Tethyan Province. The Callovian and Oxfordian Stages are based on Arkell (1956), Mouterde & Enay (1971: 16–21) and Cariou & Hantzpergue (1997: 80, 84, 362), and the Kimmeridgian to Berriasian Stages on Howarth (1992: 599–601) and Cariou & Hantzpergue (1997). The horizons of the dateable ammonite faunas in Yemen are shown by asterisks (*), followed by numbers which correspond to the ammonite faunas described on pp. 101–103.

STAGES		AMMONITE ZONES	MEMBERS	FORMATIONS
BERRIASIAN		*Fauriella boissieri* *Tirnovella occitanica* *Pseudosubplanites euxinus*	*14 *13 Mintaq *12	HAJAR
TITHONIAN	U	*Durangites* *Micracanthoceras microcanthum*	*11 *10 *9 Arus	
	L	*Micracanthoceras ponti* *Semiformiceras fallauxi* *Semiformiceras semiforme* *Neochetoceras darwini* *Hybonoticeras hybonotum*	Disconformity/unconformity	
KIMMERIDGIAN	U	*Hybonoticeras beckeri* *Aulacostephanus eudoxus* *Aspidoceras acanthicum*	*8 *7 Kilya *6	NAIFA
	L	*Crussoliceras divisum* *Ataxioceras hypselocyclum* *Sutneria platynota*	*5 Billum	
OXFORDIAN	U	*Subnebrodites planula* *Epipeltoceras bimammatum* *Dichotomoceras bifurcatum*	*4	
	M	*Gregoryceras transversarium* *Perisphinctes plicatilis*		*3 MADBI
	L	*Cardioceras cordatum* *Quenstedtoceras mariae*		*2
CALLOVIAN	U	*Quenstedtoceras lamberti* *Peltoceras athleta*		
	M	*Erymnoceras coronatum* *Reineckeia anceps*		*1 SHUQRA
	L	*Sigaloceras calloviense* *Proplanulites koenigi* *Macrocephalites herveyi*		
BATHONIAN				KOHLAN

Museum, London, while those with the prefix SM F. are in the Sedgwick Museum, Cambridge. Whorl measurements are given in the order: diameter (D), whorl height (Wh), whorl breadth (Wb), umbilical width (U); numbers in brackets after Wh, Wb and U are proportions of the diameter. The type species of genera were all fixed by 'original designation', except when stated otherwise. The exact horizons of the great majority of the ammonites described here are shown on figs 2, 3, 5, 6, 12, 16, 18 and 20 of the preceding paper (Howarth & Morris, 1998). Each ammonite figured in the plates is related to its appropriate fauna as described on pp. 101–103.

Order **AMMONOIDEA** Zittel, 1884
Suborder **AMMONITINA** Hyatt, 1889
Superfamily **HAPLOCERATACEAE** Zittel, 1884
Family **OPPELIIDAE** Douvillé, 1890
Subfamily **TARAMELLICERATINAE** Spath, 1928
Genus ***TARAMELLICERAS*** Del Campana, 1904

TYPE SPECIES. *Ammonites trachinotus* Oppel, 1863, subsequently designated by H. Douvillé, 1879 [for *Neumayria* Bayle, 1878 (*non* De Stefani, 1877), for which *Taramelliceras* Del


1
*
2
3a
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5a
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4
8b
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8a
6a
6b
5b
7b
7a
7d
7c
*
9b
9a
9d
10
9c
*
11a
*
11b

Campana, 1904, was a replacement name (a *nom. nov.*)].

Subgenus ***TARAMELLICERAS*** Del Campana, 1904

Taramelliceras (Taramelliceras) pseudoflexuosum (Favre, 1875) Pl. 1, figs 1, 2

1846 *Ammonites flexuosus costatus* Quenstedt: 126, pl. 9, fig. 1.
1875 *Ammonites flexuosus* Münster; Favre: 25, pl. 1, figs 13, 14.
1876 *Ammonites (Oppelia) flexuosus* Münster; Favre: 40, pl. 3, fig. 6.
1877 *Ammonites pseudoflexuosus* Favre: 29, pl. 2, figs 9, 10; pl. 3, fig. 1.
1887 *Ammonites flexuosus costatus* Quenstedt: 904, pl. 97, fig. 10.
1893 *Neumayria pseudoflexuosa* (Favre); Choffat: 23, pl. 16, figs 15–17.
1928 *Taramelliceras pseudoflexuosum* (Favre); Spath: 141, pl. 18, fig. 2.
1955 *Taramelliceras (Taramelliceras) pseudoflexuosum* (Favre); Hölder: 117, figs 115–119, pl. 19, fig. 23.
?1959 *Taramelliceras pseudoflexuosum* (Favre); Collignon: pl. 99, fig. 374.

MATERIAL. Two specimens, CA703–04, from the Breadloaf Concretions in the Kilya Member, on the east side of Wadi Arus, and three, CA1052–54, from doggers 8.5 m above the base of the Kilya Member in Wadi Kilya.

DESCRIPTION. One of the small specimens from Wadi Arus is 37 mm diameter, is partly crushed, and has half a whorl of body-chamber; the other is a short fragment of a smaller whorl. A larger example from Wadi Kilya is crushed flat, so the venter is not seen, and is part of a whorl at about 60 mm diameter; the other two are small fragments. The whorls are very involute. The ribs are flexuous; most bifurcate at the backwards bend at the middle of the whorl side, where some intercalated secondaries also start; the secondary ribs swing forwards and each has a small ventro-lateral swelling or tubercle and ends in a small mid-ventral tubercle.

REMARKS. These specimens are like the smaller whorls of the examples figured by Spath (1928: pl. 18, fig. 2) and Hölder (1955: pl. 19, fig. 23). The species was recorded by Spath from the Eudoxus Zone in Cutch, and by Hölder (1955: 140) from beds equivalent to the Eudoxus and Beckeri Zones in southern Germany.

OCCURRENCE. Lower marly part of the Kilya Member, Naifa Formation, east side of Wadi Arus and Wadi Kilya; Beckeri Zone, Upper Kimmeridgian.

Taramelliceras (Taramelliceras) cf. *intersistens* Hölder, 1955 Pl. 1, figs 3, 4

1955 *Taramelliceras intersistens* Hölder: 116, pl. 19, fig. 27.

MATERIAL. Four specimens, CA705–08, from the Breadloaf Concretions in the Kilya Member, east side of Wadi Arus.

DESCRIPTION. All are fragments of specimens up to 60 mm diameter. The whorls are involute and compressed, and have a small umbilicus. Sinuous striae on the inner part of the whorl strengthen into curved forwardly inclined ribs on the outer part of the whorl and are only slightly diminished in strength in the middle of the venter. The smallest whorl visible (25 mm diameter) is more striate throughout. No tubercles are developed.

REMARKS. These small specimens are associated with *T. (T.) pseudoflexuosum*, from which they differ in being striate on the inner half of the whorl and in lacking the row of mid-ventral tubercles. A similar striate to fine-ribbed specimen from the Beckeri Zone in southern Germany was given the name *T. intersistens* by Hölder, which is the tentative identification for the Yemeni specimens.

OCCURRENCE. Lower marly part of the Kilya Member, Naifa Formation, east side of Wadi Arus; Beckeri Zone, Upper Kimmeridgian.

Taramelliceras (Taramelliceras) compsum (Oppel, 1863) Pl. 1, fig. 8

1846 *Ammonites flexuosus gigas* Quenstedt: 126, pl. 9, fig. 2.
1863 *Ammonites holbeini* Oppel: 213.
1863 *Ammonites compsus* Oppel: 215, pl. 57, fig. 1.
1873 *Oppelia holbeini* (Oppel); Neumayr: 166, pl. 33, fig. 1.
?1879 *Oppelia hemipleura* Fontannes: 47, pl. 6, fig. 6.
1887 *Ammonites flexuosus gigas* Quenstedt: 909, pl. 98, figs 8–12.
1887 *Ammonites flexuosus crassatus* Quenstedt: 912, pl. 99, figs 1, 2.
1928 *Taramelliceras* cf. *compsum* (Oppel); Spath: 137, pl. 18, fig. 10.
1955 *Taramelliceras (Taramelliceras) compsum* (Oppel); Hölder: 110, figs 94–98, 100–110; pl. 19, fig. 22 (see for a more complete synonymy).

PLATE 1

Figs 1, 2 *Taramelliceras (Taramelliceras) pseudoflexuosum* (Favre), Kilya Member, lower marls (fauna 7). **1,** CA703, Breadloaf Concretions, east cliff, Wadi Arus. **2,** CA1053, 8.5 m above base of Kilya Member, Wadi Kilya.

Figs 3, 4 *Taramelliceras (Taramelliceras)* cf. *intersistens* Hölder, Breadloaf Concretions, Kilya Member (fauna 7), east cliff, Wadi Arus. **3a, 3b,** CA705; **4,** CA707.

Fig. 5 *Taramelliceras (Metahaploceras) subsidens* (Fontannes), Kilya Member, upper marly part (fauna 8), Wadi Kilya. **5a, 5b,** CA1062.

Fig. 6 *Lamellaptychus*, ammonite bed, base of middle limestone part of Kilya Member (fauna 7), Naifa Cliff. **6a, 6b,** SM F.13415.

Fig. 7 *Glochiceras (Lingulaticeras) pseudocarachteis* (Favre), Breadloaf Concretions, Kilya Member (fauna 7), east cliff, Wadi Arus. **7a-7d,** CA717; 7a, 7b, ×1, 7c, 7d, ×2.

Fig. 8 *Taramelliceras (Taramelliceras) compsum* (Oppel), near top of middle limestone part of Kilya Member (fauna 7), Wadi Kilya. **8a, 8b,** CA1055, ×0.59.

Fig. 9 *Haploceras staszycii* (Zejszner), Breadloaf Concretions, Kilya Member (fauna 7), east cliff, Wadi Arus. **9a-9d,** CA709; 9a, 9b, ×1, 9c, 9d, ×2.

Fig. 10 *Uhligites kraffti* (Uhlig), 4 m above base of Mintaq Member (fauna 11), eastern Jebel Billum, CA815, ×1.5.

Fig. 11 *Haploceras umbilicatum* sp. nov., bed 57, Mintaq Member (fauna 13), Mintaq Salt Dome. **11a, 11b, paratype**, CA577, ×0.69.

All figures in the plates are natural size, unless stated otherwise; asterisks (*) indicate the position of the end of the phragmocone.

1959 *Taramelliceras holbeini* (Oppel); Collignon: pl. 92, fig. 419.
?1984 *Taramelliceras (Taramelliceras) trachinotum* (Oppel); Verma & Westermann: 35, pl. 3, fig. 2.

MATERIAL. Four specimens, CA1055–58, from limestones near the top of the middle limestone part of the Kilya Member, Naifa Formation, in Wadi Kilya.

DESCRIPTION. The material consists of four large adult body-chambers complete up to their final mouth-borders at diameters of 208, 145, 142 and 135 mm respectively. The preservation is rough, and all are flattened to some extent. The whorls are highly involute, and have flat sides (probably accentuated by the lateral crushing), an obtuse angle at the ventro-lateral edge, and an arched, tabulate venter. No lateral ribs or striae can be seen on the rough preservation (though the sides of the whorl appear to be genuinely smooth), but prominent tubercles at the ventro-lateral edge are elongated obliquely forwards; there are 15 such tubercles per half whorl at 180 mm diameter on the largest specimen. The position of the final adult septum is clear in three of the specimens and the body-chamber is 0.61–0.67 whorls long. Few details of the suture-lines can be seen.

REMARKS. These large, flat, nearly smooth body-chambers are typical of *T. compsum*, which occurs in the Eudoxus and Beckeri Zones in southern Germany (Hölder, 1955: 140). They are easily distinguished from similar-sized body-chambers of *T. trachinotum* (Oppel), which are much more coarsely ornamented throughout growth and are usually somewhat older in the Divisum Zone and possibly lower. A few similar specimens described by Spath (1928) from Cutch, Collignon (1959) from Madagascar and Verma & Westermann (1984) from Mombasa, are mostly from the Beckeri Zone. The rather similar large body-chambers of *T. (Metahaploceras) pascoei* (Spath, 1928: 147, pl. 8, fig. 3), from the Kimmeridgian of Jurun, Cutch, differ in having rounded-elliptical rather than quadrate whorls, and less prominent ventro-lateral tubercles.

OCCURRENCE. Middle part of the Kilya Member, Naifa Formation, Wadi Kilya; Beckeri Zone, Upper Kimmeridgian.

Taramelliceras spp. indet.

MATERIAL. Two fragments, CA972–73, from the ammonite bed at the bottom of the middle limestone part of the Kilya Member, Naifa Cliff; one is smooth, crushed and about 120 mm diameter, and has a sharp venter due to crushing; the other has a whorl height of 40 mm, feeble striate ribs and widely spaced ventro-lateral tubercles.

CA1059 is a fragment of part of a very large whorl from limestones near the top of the middle limestone part of the Kilya Member in Wadi Kilya. It has a whorl height of 85 mm, flat whorl sides, flexuous ribs that are projected strongly on the venter, and only very rudimentary ventro-lateral tubercles, and differs from the body-chambers of *T. compsum* that occur in the same bed in its ribbing and lack of prominent tubercles.

Two specimens, CA1060–61, from the lower marly part of the Kilya Member in Wadi Kilya, are poorly preserved and about 40 mm diameter; one has moderate to fine flexuous ribs, the other has prominent ventro-lateral tubercles, but the preservation is very rough and neither is specifically determinable.

OCCURRENCE. Lower and middle parts of Kilya Member, Naifa Formation; Beckeri Zone, Upper Kimmeridgian.

Subgenus ***METAHAPLOCERAS*** Spath, 1925

TYPE SPECIES. *Metahaploceras affine* Spath, 1925 (=*Ammonites strombecki* Oppel, 1858).

Taramelliceras (Metahaploceras) subsidens (Fontannes, 1879) Pl. 1, fig. 5; Pl. 3, fig. 6

1879 *Oppelia subsidens* Fontannes: 50, pl. 7, fig. 7.
1928 *Taramelliceras* aff. *holbeini* (Oppel); Spath: 138, pl. 14, fig. 14.
1959 *Taramelliceras subsidens* (Fontannes); Berckhemer & Hölder: 76.

MATERIAL. Nine specimens, CA1062–70, from the upper marly part of the Kilya Member in Wadi Kilya.

DESCRIPTION. These four complete ammonites and five fragments are all small, the largest being a slightly crushed imperfect specimen 75 mm diameter, while the others are uncrushed. The whorls are involute and have a smoothly rounded elliptical whorl section, a fairly sharp umbilical edge and vertical or undercut umbilical walls. The ornament consists of weak or striate flexuous ribs that are prorsiradiate on the inner half of the whorl, bent backwards at the middle of the side of the whorl, where most of them bifurcate, then curve well forwards on the outer half of the whorl. Small indistinct ventro-lateral tubercles occur on every 3rd or 4th rib, and there are very small mid-siphonal tubercles on each rib. The ribs have become only slightly stronger on the outer half of the whorl of the largest specimen at 74 mm diameter. Parts of the suture-lines that are visible on several specimens are complex, with much divided lobes and saddles. Up to half a whorl of body-chamber is present on some specimens, but there are no adult features and all are thought to be immature individuals.

MEASUREMENTS

	D	Wh	Wb	U
CA1062	51.0	26.2 (0.51)	15.6 (0.31)	8.9 (0.17)
CA1062	34.4	18.5 (0.54)	11.6 (0.34)	7.2 (0.21)
CA1063	41.0	21.0 (0.51)	13.4 (0.33)	7.1 (0.17)

REMARKS. These small specimens are not thought to be immature individuals or microconchs of *Taramelliceras (T.) compsum*, large body-chambers of which occur in the Beckeri Zone in Wadi Kilya and have stronger ribs and tubercles and more quadrate flat-sided whorls at similar sizes (Hölder, 1955: 110, figs 98, 104–108). In fact the involute, smoothly rounded whorls, weak ornament and complex suture-line are characters of the subgenus *Metahaploceras*. Fontannes' original figure, although it is a drawing and only 43 mm diameter, is a close match for the Yemeni specimens. A very similar specimen from a poorly known horizon in the Kimmeridgian at Cutch (Spath, 1928: 138, pl. 14, fig. 14) has rounded whorls, weak ornament and complex suture-lines, and is still septate at its maximum diameter of 97 mm.

OCCURRENCE. Upper part of the Kilya Member, Naifa Formation, Wadi Kilya; Hybonotum Zone, Lower Tithonian.

Lamellaptychus Pl. 1, fig. 6

MATERIAL. 20 specimens: six, SM F.13415–18, F.13457–58, from the bottom of the middle limestone part of the Kilya Member in Naifa Cliff; 14, CA1071–84 (7 left and 7 right valves), from the lower marly part of the Kilya Member in Wadi Kilya.

REMARKS. All are fragments of aptychi up to 40 mm long; they are covered with coarse concentric folds on the outer surface and with fine concentric striae on the inner surface (Pl. 1, fig. 6). As typical

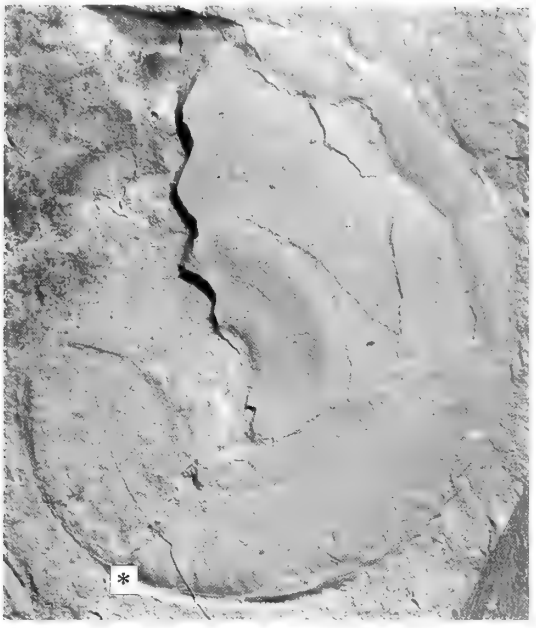


Fig. 1 *Steblites plicodiscus* (Waagen), on limestone pavement formed by top bed of Billum Member (fauna 6), below west cliff, Wadi Arus; ×1.1 (from a colour photograph taken in the field).

aptychi of the family Oppeliidae, they are probably from *Taramelliceras*, species of which occur in both parts of the Kilya Member from which the aptychi have been obtained.

OCCURRENCE. Lower and middle parts of the Kilya Member, Naifa Formation, Naifa Cliff and Wadi Kilya; Beckeri Zone, Upper Kimmeridgian.

Subfamily **STREBLITINAE** Spath, 1925
Genus ***STREBLITES*** Hyatt, 1900

TYPE SPECIES. *Ammonites tenuilobatus* Oppel, 1862.

Streblites plicodiscus (Waagen, 1875) Fig. 1

1875 *Oppelia plicodiscus* Waagen: 56, pl. 10, fig. 5.
1928 *Steblites plicodiscus* (Waagen); Spath: 148, pl. 16, fig. 2; pl. 17, fig. 1.
1928 *Streblites leptodiscus* Spath: 150, pl. 16, fig. 1.
1959 *Steblites plicodiscus* (Waagen); Collignon: pl. 111, figs 409, 410.
1959 *Steblites habyensis* Spath; Collignon: pl. 111, fig. 411.
1984 *Steblites habyensis* Spath; Verma & Westermann: 36, pl. 3, fig. 3.

MATERIAL. Many specimens can be seen on the limestone pavement formed by the top 1 m thick bed of the Billum Member, below the cliff with microbialite boulders on the west side of Wadi Arus; photographs were taken of four specimens in the field.

DESCRIPTION. All specimens are crushed flat on the bedding plane, though slight relief and the curvature of the side of the whorl is retained in the body-chamber of some examples. Specimens of up to 125 mm diameter were seen, several with about 0.6 whorls of body-chamber and parts of the final mouth-border. The highly complex suture-line is visible at the end of the phragmocone in some. The whorls are involute oxycones, with an angled or bluntly rounded venter. At sizes of 50–100 mm diameter the whorl height is 52–56% of the diameter and the umbilical width is 11%. Feeble falcoid ribs or striae can be seen crossing parts of the side of the whorl, though they are very weak in the middle part of the whorl side and more prominent near the venter.

REMARKS. Waagen's sole original specimen was only 31 mm diameter, but Spath re-interpreted the species from more than 20 larger well-preserved specimens, which he claimed showed the complete range from small 'smooth young to smooth adult' (Spath, 1928: 148), some of which were still septate at 110 mm diameter. The ribs are always feeble except for the forwardly inclined crescents at the ventral edge. The amount of variation in rib strength is not clear from either the original Cutch or the present Yemen specimens, so it is not clear whether *Streblites habyensis* Spath (1928: 151, pl. 8 fig. 1) with its slightly stronger ribs is a synonym, though the nearly smooth species *S. leptodiscus* Spath (1928: 150, pl. 16, fig. 1) does not appear to be different. Their age in Cutch is Eudoxus and Beckeri Zones. Specimens that almost certainly belong to the same species were described by Verma & Westermann (1984) from the Hybonotum Zone at Mombasa, and several specimens from the same Eudoxus to Hybonotum Zone age range were described by Collignon (1959) from Madagascar.

OCCURRENCE. Top bed of the Billum Member, Naifa Formation, west cliff of Wadi Arus; Eudoxus or Beckeri Zones, Upper Kimmeridgian.

Genus ***UHLIGITES*** Kilian, 1913

TYPE SPECIES. *Streblites kraffti* Uhlig, 1903, subsequently designated by Roman (1938).

Uhligites kraffti (Uhlig, 1903) Pl. 1, fig. 10

1903 *Streblites kraffti* Uhlig: 44, pl.4, fig.1; pl.5, fig.1.

MATERIAL. Two specimens, CA815–16, from a limestone 4 m above the base of the Mintaq Member, and one, CA860, from the shell bed 26 m above the base of the Arus Member, all in eastern Jebel Billum.

DESCRIPTION. CA815 is a well-preserved 40 mm diameter specimen; complex suture-lines, with a large lateral lobe; compressed rounded venter, oval whorl section, small umbilicus, very low obsolescent flexuous ribs. CA816 is a similar 50 mm diameter specimen with complex sutures. CA860 is only 20 mm diameter.

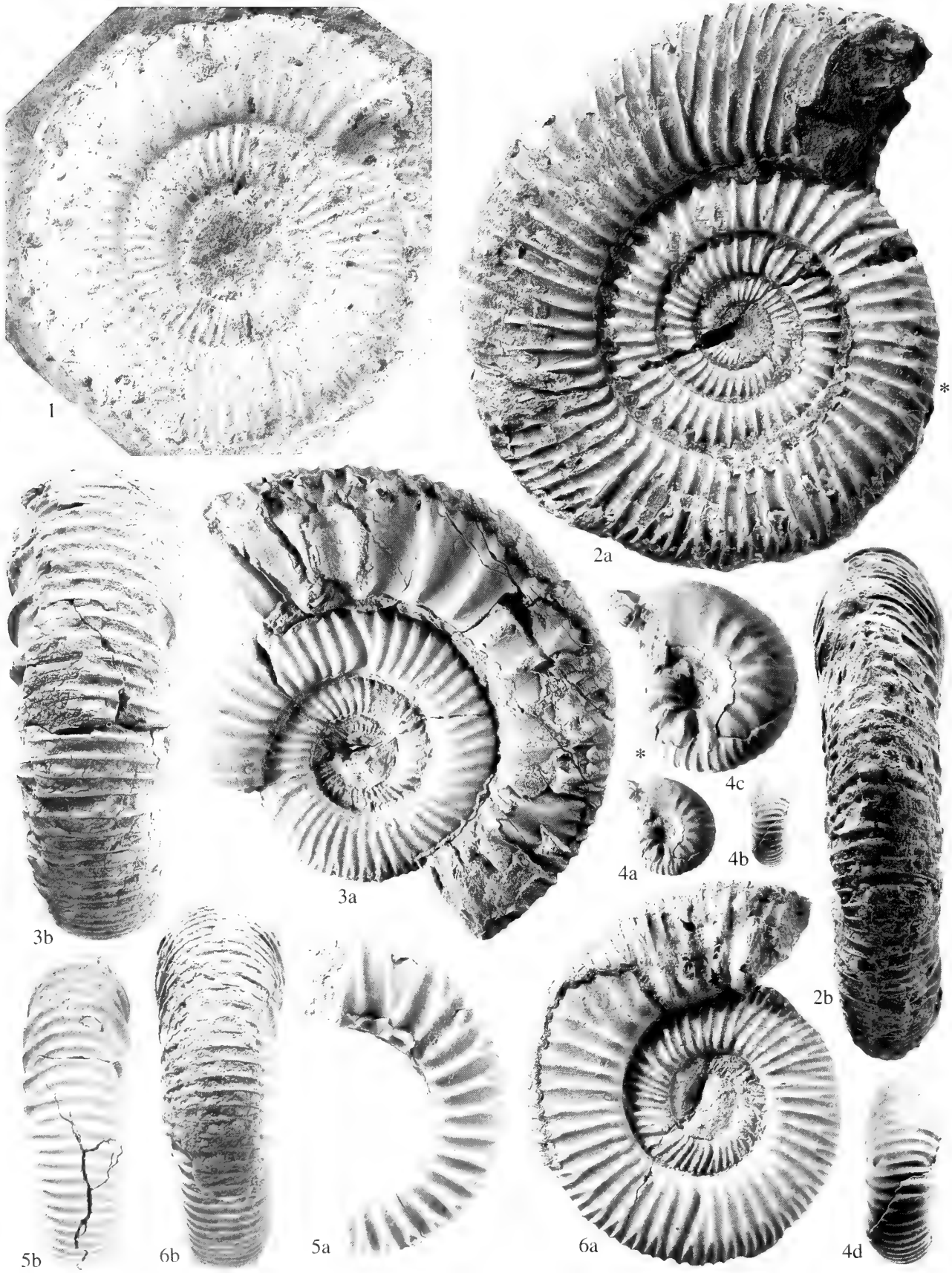
REMARKS. *U. kraffti* has a narrowly rounded, not crenulated, keel as in '*Gymnodiscoceras*'; many of Uhlig's (1903) figured specimens have crenulated keels, which are hollow and floored, and are missing on casts of phragmocones; possibly all *Uhligites* have such keels, and *Gymnodiscoceras* is a synonym.

OCCURRENCE AND AGE. Arus Member and basal Mintaq Member, Hajar Formation, eastern Jebel Billum; Durangites Zone, Upper Tithonian.

Family **HAPLOCERATIDAE** Zittel, 1884
Genus ***HAPLOCERAS*** Zittel, 1870

TYPE SPECIES. *Ammonites elimatus* Oppel, 1868, subsequently designated by Spath (1923b).

REMARKS. Dimorphism in *Haploceras* was described by Enay &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Cecca (1986), who recognized that the undulations on the venter are a feature of microconchs, and they arranged most of the species proposed or discussed by Zejszner (1846), Oppel (1865), Zittel (1868, 1870) and Fontannes (1879) into dimorphic pairs.

Haploceras staszycii (Zejszner, 1846) Pl. 1, fig. 9

1846 *Ammonites staszycii* Zejszner: pl. 4, figs 3a–3d.
1870 *Haploceras staszycii* (Zejszner); Zittel: 50, pl. 27, figs 2–6.
1875 *Haploceras staszycii* (Zejszner); Pillet & Fromental: 109, pl. 5, figs 10, 11.
1879 *Haploceras staszycii* (Zejszner); Fontannes: 11, pl. 2, fig. 4.
1906 *Haploceras* sp. indet., Burckhardt: 90, pl. 24, figs 1–3.
1959 *Haploceras elimatum* (Oppel); Collignon: pl. 142, figs 536, 537.
?1959 *Haploceras staszycii* (Zejszner); Collignon: pl. 142, fig. 539.
1961 *Haploceras staszycii* (Zejszner); Donze & Enay: 43.

MATERIAL. Eight specimens, CA709–16, from the Breadloaf Concretions in the Kilya Member, east side of Wadi Arus.

DESCRIPTION. The collection consists of one adult microconch with its complete mouth-border at 23.8 mm diameter; part of a phragmocone of 24.5 mm diameter that is probably a microconch; another microconch with a phragmocone 16.5 mm diameter followed by half a whorl of incomplete body-chamber up to 25 mm diameter; a fragment of the outer part of the body-chamber of a large macroconch at 75–80 mm diameter; and four small specimens of 17–22 mm diameter. The whorls are involute and moderately thick, with a small umbilicus, and a rounded whorl section in which the whorl sides are gently convex, the umbilical walls rounded and slightly undercut, and the venter is evenly arched. Flexuous radial striae bend backwards at the middle of the whorl side, then become stronger on the venter, especially on the adult body-chamber of the microconch, where they form mid-ventral undulations. The adult mouth-border of the microconch is immediately preceded by a slight constriction on the outer half of the whorl, then there is a collar-like rostrum on the venter; a forwards projection in the mouth-border in the middle of the whorl side follows the shape of the striae and forms a small rudimentary 'lappet', but there is no long spatulate lappet as in *Glochiceras*.

MEASUREMENTS

	D	Wh	Wb	U
CA709	21.7	11.1 (0.51)	7.5 (0.35)	3.8 (0.18)
CA710	24.0	13.5 (0.56)	8.6 (0.36)	3.5 (0.15)

REMARKS. The two main species that occur abundantly in the Beckeri and Hybonotum Zones are *Haploceras staszycii* (Zejszner) and *H. carachtheis* (Zejszner). *H. staszycii* is based on a 60 mm diameter original specimen (a macroconch) figured by Zejszner, which is like the much smaller Yemeni specimens in having a small umbilicus (U/D = 0.17) and gently rounded whorl sides. *H. carachtheis* (Zejszner, 1846: pl. 4, fig. 1) differs in being less involute (U/D = 0.26–0.30) and having flat whorl sides. In both species the microconchs have ventral undulations on the final half whorl of body-chamber. *H. elimatum* (Oppel; Zittel, 1868: 79, pl. 13, figs 1–7) occurs mainly higher in the Tithonian, and has slightly more evolute whorls, and a distinctive whorl section, in which the greatest whorl breadth is near the umbilical edge and the gently rounded whorl sides converge towards a narrowly rounded venter. *H. subelimatum* Fontannes (1879: 12, pl. 2, figs 5, 6) is also somewhat younger in age, and has rounded compressed and even more evolute whorls. *H. tithonius* (Oppel; Zittel, 1868: 82, pl. 14, figs 1–3) and *H. leiosoma* (Oppel; Zittel, 1868: 86, pl. 14, figs 5, 6) are both very involute (U/D = ca.0.09), and have flat whorl sides and a distinctive funnel-shaped umbilicus. Three specimens from the Lower Tithonian of Madagascar figured by Collignon (1959: pl. 142, figs 536, 537, 539) appear to be examples of *H. staszycii* rather than *H. elimatum* for which they do not have the characteristic whorl sides converging towards the venter. Many well-preserved *Haploceras* from Mazapil, northern Mexico, were described by Burckhardt (1906), mostly as new Mexican species, but one specimen identified as *Haploceras* sp. ind. (Burckhardt, 1906: 90, pl. 24, figs 1, 2) is closely similar, if not identical, to the Yemeni specimens.

The presence of *Haploceras* in the Breadloaf Concretions in the lower part of the Kilya Member is important for confirming the dating of the other ammonites in these concretions and also the more abundant ammonites at Naifa Cliff that are slightly higher in the succession. The oldest *Haploceras* are found in the uppermost part of the Eudoxus Zone in south-western France and Germany, in White Jura δ4 (horizon 18 of the Crussol (Ardèche) section). *H. staszycii* is recorded from that horizon and throughout the overlying Beckeri Zone (White Jura ε1) according to the detailed records of Hölder & Ziegler (1959: 168, 181). Topmost Eudoxus Zone (and more probably Beckeri Zone) is therefore the oldest age that can be ascribed to the Perisphinctids and other ammonites that occur with *Haploceras* in the Kilya Member in Wadi Hajar.

OCCURRENCE. The lower part of Kilya Member, Naifa Formation, east side of Wadi Arus; Beckeri Zone, Upper Kimmeridgian.

Haploceras umbilicatum sp. nov. Pl. 1, fig. 11; Pl. 3, fig. 1

HOLOTYPE. CA576 from bed 57 of the Mintaq Member, Mintaq Salt Dome.

PARATYPES. CA577 from the same bed as the holotype, and CA578 from bed 69 in the same section.

DIAGNOSIS. Has moderately compressed whorls and a larger umbilicus that other species of *Haploceras*: in macroconchs the umbilical width is 30–34% of the diameter at 100–135 mm diameter. The whorl section is elliptical with no traces of umbilical or ventrolateral edges. Smooth except for sinuous growth striae or very reduced ribs.

DESCRIPTION. The holotype is the largest specimen, 136 mm diameter at its (?adult) mouth border; it has a body-chamber that is apparently more than 320° long, and parts of a poorly preserved, recrystallized phragmocone. The larger paratype (CA577) is 118 mm diameter at its incomplete aperture and has a body-chamber 250° long following the recrystallized whorls of the phragmocone. The smaller paratype (CA578) from bed 69 is a quarter whorl

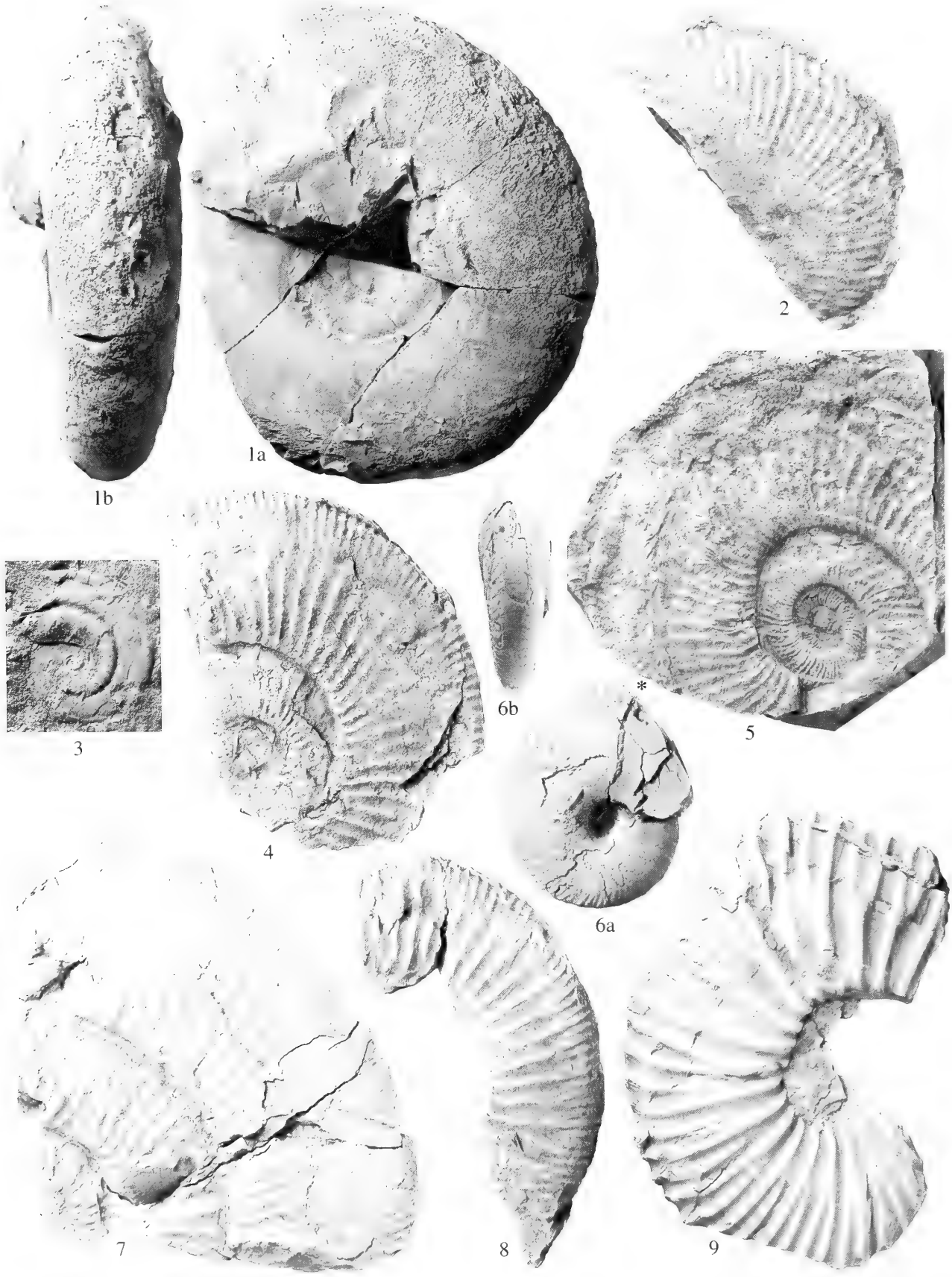
PLATE 2

Figs 1, 2 *Torquatisphinctes naifaensis* sp. nov. **1, paratype**, Breadloaf Concretions, Kilya Member (fauna 7), east cliff, Wadi Arus, SM F.12168, ×0.58. **2a, 2b, holotype**, 0.5 m above base of middle limestone part of Kilya Member, Naifa Cliff, CA974.

Figs 3, 6 *Katroliceras formosum* Spath, upper marly part of Kilya Member (fauna 8), Wadi Kilya. **3a, 3b,** CA1104; **6a, 6b,** CA1105, wholly septate.

Fig. 4 *Sutneria weidmanni* Zeiss, Breadloaf Concretions, Kilya Member (fauna 7), east cliff, Wadi Arus. **4a-4d,** SM F.12163; 4a, 4b, ×1; 4c, 4d, ×2.

Fig. 5 *Subdichotomoceras ?latissimum* (Zwierzycki), upper marly part of Kilya Member (fauna 8), Wadi Kilya. **5a, 5b,** CA1145.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fragment of a partly crushed body-chamber with part of the (?adult) mouth-border preserved at a diameter of about 120 mm. They all have a smoothly rounded elliptical whorl-section, and a wide, open umbilicus. The ornament consists only of sinuous growth striae which are prominent enough near the apertures to resemble obsolescent ribbing, and the apertures follow the line of these striae. In the holotype and the fragmentary paratype the apertures are probably adult mouth-borders. Traces of the final suture-line can be seen on CA577, and the first lateral saddle appears to be high and complex.

MEASUREMENTS

	D	Wh	Wb	U
CA576, holotype	135.5	50.1 (0.37)	—	45.8 (0.34)
CA576, holotype	110.0	40.4 (0.37)	31.3 (0.28)	37.0 (0.34)
CA576, holotype	82.0	32.8 (0.40)	24.2 (0.29)	25.3 (0.31)
CA577, paratype	117.5	46.8 (0.40)	32.4 (0.28)	35.5 (0.30)

REMARKS. After a considerable amount of variation in the Lower Tithonian with several species recognized, *Haploceras* became less common and less variable in the Upper Tithonian and Berriasian, the main species now being *H. elimatum* (Oppel). With the recognition of dimorphism in the genus, *H. elimatum* and *H. carachtheis* (Zejszner, 1846) were taken as macroconch and microconch respectively of a pair, for which the earlier name, *H. carachtheis*, was used by Enay & Cecca (1986: 52). The largest specimen of *H. elimatum* described by Zittel (1868: 80) was 145 mm diameter, and specimens of 50–70 mm diameter have an umbilicus of 18–23% of the diameter. Compared with these the Yemeni species has a much larger umbilicus of 30–34% of the diameter at 82–135 mm diameter. The three known examples are macroconchs, and similarly widely umbilicate microconchs have yet to be found.

OCCURRENCE. Mintaq Member, Hajar Formation, Mintaq Salt Dome; Occitanica Zone, Berriasian.

Genus ***GLOCHICERAS*** Hyatt, 1900

TYPE SPECIES. *Ammonites nimbatus* Oppel, 1863.

Subgenus ***GLOCHICERAS*** Hyatt, 1900

Glochiceras (Glochiceras) subclausum (Oppel, 1863) Pl. 3, fig. 3

1850 *Ammonites canaliculatus* Münster; d'Orbigny: 525, pl. 199, fig. 3.
1863 *Ammonites subclausus* Oppel: 190, pl. 52, fig. 3.
1887 *Ammonites subclausus* Oppel; Quenstedt: 842, pl. 92, fig. 15.
1901 *Oppelia subclausa* (Oppel); Loriol: 16, pl. 1, fig. 6
1902 *Harpoceras subclausum* (Oppel); Loriol: 22, pl. 2, figs 1–3.
1958b *Glochiceras (Glochiceras) subclausum* (Oppel); Ziegler: 107, figs 11–13; pl. 10, figs 3–5.

MATERIAL. Five specimens, CA817–21, from the lower half of the Billum Member, in the road cutting at the western end of Jebel Billum.

DESCRIPTION. All are small flattened specimens, the largest being a complete microconch with a mouth-border and lappets at 30 mm diameter, the other four being fragments of smaller specimens. The whorls are involute (U/D = 0.22) and are smooth, except for a prominent mid-lateral groove, which is developed at least from a diameter of 12 mm and is not visible in the umbilicus on the inner whorls due to the overlap of the whorls. The groove runs into the slender neck of the lappet of the complete specimen, but the spatulate anterior end of the lappet is not preserved. Measurements of CA817: at 28.5 mm diameter: 13.6 (0.48), — (—), 6.6 (0.23).

REMARKS. These ammonites were collected from loose material excavated from the road cutting at the western entrance to Jebel Billum. They came from lower part of the Billum Member and are of interest in dating that horizon. The complete specimen is an exact match for Oppel's (1863: pl. 52, fig. 3) drawing of his holotype (refigured by Ziegler, 1958b: pl. 10, fig. 3), and is very like the specimens figured by de Loriol (1902: pl. 2, figs 1–3). With its mouth-border and lappets at 30 mm diameter it is exactly the same size as the average of 110 microconchs from the Jura of France and Germany measured by Ziegler (1958b: 108 – average 30 mm diameter, range 22–43 mm). In that area, Ziegler (1958b: 156, fig. 66) recorded *G. (G.) subclausum* from the Middle Oxfordian, Transversarium Zone (White Jura lower α). From the Bimammatum Zone date of the Perisphinctids low in the Billum Member, it is apparent that *G. (G.) subclausum* must be at least as high as Bimammatum Zone in Yemen, and this is an upwards extension of its stratigraphical range in southern Europe. The other species of *G. (Glochiceras)* from higher in the Upper Oxfordian and Kimmeridgian described by Ziegler (1958b) lack the lateral groove on the inner whorls. *Hildoglochiceras* is much more evolute, and its prominent spiral groove is always visible on the inner whorls in the umbilicus.

OCCURRENCE. Lower half of the Billum Member, Naifa Formation, western entrance road cutting to Jebel Billum; Bimammatum Zone, Upper Oxfordian.

Subgenus ***LINGULATICERAS*** Ziegler, 1958

TYPE SPECIES. *Ammonites nudatus* Oppel, 1858.

Glochiceras (Lingulaticeras) pseudocarachteis (Favre, 1880) Pl. 1, fig. 7

1880 *Ammonites (Haploceras) pseudocarachteis* Favre: 30, pl. 2, fig. 11.

PLATE 3

Fig. 1 *Haploceras umbilicatum* sp. nov., bed 57, Mintaq Member (fauna 13), Mintaq Salt Dome. **1a, 1b, holotype**, CA576, ×0.7.
Fig. 2 *Epimayaites* sp. indet., basal 5 m of Billum Member (fauna 4), 1 km east of Al Ma'abir road/river crossing; CA1085.
Fig. 3 *Glochiceras (Glochiceras) subclausum* Oppel, lower half of Billum Member (fauna 4), road cutting at western entrance to Jebel Billum, CA817.
Figs 4, 5 *Larcheria gredingensis* (Wegele). **4,** 7–8 m above base of Billum Member (fauna 4), Perisphinctid Cliff, eastern Jebel Billum, CA825, ×0.75. **5,** basal part of Billum Member (fauna 4), 1 km east of Al Ma'abir road/river crossing, CA1088.
Fig. 6 *Taramelliceras (Metahaploceras) subsidens* (Fontannes), upper marly part of Kilya Member (fauna 8), Wadi Kilya, CA1063.
Figs 7, 8 *Orthosphinctes polygyratus* (Reinecke). **7,** 7–8 m above base of Billum Member (fauna 4), Perisphinctid Cliff, eastern Jebel Billum, CA826, ×0.68; **8,** lower half of Billum Member, road cutting at western entrance to Jebel Billum, CA836, ×0.73.
Fig. 9 *Paryphoceras grayi* (Spath), basal 8 m of Billum Member (fauna 4), 1 km east of Al Ma'abir road crossing, CA1087.

1958b *Glochiceras (Lingulaticeras) pseudocarachteis* (Favre); Ziegler: 144, figs 55, 56; pl. 14, figs 11–13.

MATERIAL. Four specimens, CA717–20, from the Breadloaf Concretions in the Kilya Member, east side of Wadi Arus.

DESCRIPTION. The largest specimen is complete up to its partly intact mouth-border at 22.1 mm diameter; the mouth-border is flared at the ventral rostrum and is preserved near the umbilicus, but it is missing at the middle of the whorl side, so lappets are not preserved and it is not certain that the specimen is adult, though the umbilical seam uncoils slightly; the body-chamber is exactly half a whorl long. The three others are smaller immature specimens of 17–19 mm diameter; two have slightly more than half a whorl of body-chamber ending in a broken aperture, with the mouth-borders just missing, while the third has one-sixth of a whorl of body chamber. The whorl section is elliptical with only a slight flattening on the venter. Flexuous radial striae of low relief bend backwards at the middle of the whorl side, then curve forwards and cross the venter; they increase in relief to form low curving ribs on the venter of the body-chamber of the largest specimen.

MEASUREMENTS

	D	Wh	Wb	U
CA717	21.3	9.5 (0.45)	6.3 (0.30)	5.4 (0.26)
CA720	16.2	7.9 (0.49)	5.2 (0.32)	3.9 (0.24)
CA719	15.6	7.1 (0.46)	4.7 (0.30)	4.1 (0.26)

REMARKS. These four small specimens match Ziegler's (1958b) redescription and figures of Favre's species exactly, and in particular the size of the umbilicus (24–26% of the diameter) is correct for this species. The similar *G. (L.) modestum* Ziegler (1958b: 139, figs 52, 53; pl. 14, figs 3–5) has stronger ornament on the side of the whorl and a larger umbilicus. *G. (L.) pseudocarachteis* occurs in the Beckeri and Hybonotum Zones in southern Germany and France.

OCCURRENCE. The lower marly part of the Kilya Member, Naifa Formation, east side of Wadi Arus; Beckeri Zone, Upper Kimmeridgian.

Superfamily **STEPHANOCERATACEAE** Neumayr, 1875
Family **SPHAEROCERATIDAE** Buckman, 1920
Subfamily **MAYAITINAE** Spath, 1928

The presence of Mayaitinids is important in fixing the date of the basal part of the Billum Member as no younger than Upper Oxfordian. Of the five specimens found, two are compressed, involute fragments of fine-ribbed *Epimayaites*; the other three are more evolute body-chambers with strong biplicate ribs, here identified as *Paryphoceras*; they might be macroconchs and microconchs respectively. As common ammonites in the East African – Indian Ocean area, the last Mayaitinids are not younger than the top of the Oxfordian.

Genus ***EPIMAYAITES*** Spath, 1928

TYPE SPECIES. *Stephanoceras transiens* Waagen, 1875.

Epimayaites sp. indet. Pl. 3, fig. 2

MATERIAL. Two fragmentary specimens, CA1085–86, from the basal 5 m of the Billum Member, Naifa Formation, Bimammatum Zone, Upper Oxfordian, 1 km east of the Al Ma'abir road/river crossing.

DESCRIPTION. One is a fragment of a whorl of approximately 130 mm diameter attached to nearly half of a partly crushed inner whorl; the other is a half whorl fragment of about 80 mm diameter. The whorls are involute, have a small umbilicus, and a rounded, compressed whorl section. Fine ribs on the outer half of the whorl are projected forwards on the venter; the inner half of the sides of the whorls are almost smooth. Both are too fragmentary for specific identification.

Genus ***PARYPHOCERAS*** Spath, 1928

TYPE SPECIES. *Paryphoceras badiense* Spath, 1928 (p. 224), by original designation (Spath, 1928: 247).

SYNONYM. *Prograyiceras* Spath, 1928; type species, *Dhosaites grayi* Spath, 1924a.

REMARKS. These are smaller, more evolute Mayaitinids than *Mayaites* itself or *Epimayaites*, and are strongly ribbed to the end of growth. They are probably microconchs corresponding to the much larger sphaeroidal macroconchs of *Mayaites* and *Epimayaites*. Apart from the slightly denser ribbing of *P. badiense*, there are no differences between the type species of *Paryphoceras* and *Prograyiceras*, which are here put into synonymy, and *Paryphoceras* is chosen as the name for the group.

Paryphoceras grayi (Spath, 1924a) Pl. 3, fig. 9

1875 *Stephanoceras nepalense* (Grey); Waagen: 136, pl. 35, fig. 2.
?1875 *Stephanoceras fissum* (J. de C. Sowerby); Waagen: pl. 36, fig. 4.
1924a *Dhosaites grayi* Spath: 10 (*nom. nov.* for Waagen, 1875: 136, pl. 35, fig. 2).
?1928 *Paryphoceras stephanoides* Spath: 248 (*nom. nov.* for Waagen, 1875: pl. 36, fig. 4).
1928 *Prograyiceras grayi* (Spath); Spath: 250.
1928 *Prograyiceras tramaunense* Spath: 251, pl. 28, fig. 7; pl. 50, fig. 5.
?1931 *Prograyiceras cocosiforme* Spath: pl. 115, fig. 1.

MATERIAL. Two specimens from the basal 8 m of the Billum Member: one, CA1087, from 1 km east of the Al Ma'abir road crossing, the other, CA822, from the western end of Jebel Billum. In addition, a photograph was taken of the external mould of a specimen on a large slab of limestone 7–8 m above the base of the Billum Member at the Perisphinctid Cliff in eastern Jebel Billum.

DESCRIPTION. All specimens are laterally flattened body-chambers of 100–110 mm diameter maximum size. One is about 240° long and might be a nearly complete microconch. The whorls are involute, though the umbilicus is moderately wide, and the umbilical seam may be 'uncoiling' in the near-complete specimen (Pl. 3, fig. 9). Strong radial primary ribs bifurcate at, or just before, the middle of the side of the whorl, giving rise to equally strong secondaries which bend slightly forwards in crossing the venter. There are a few extra intercalated secondaries, and the ratio secondaries/primaries is 2.1/1.

REMARKS. This is the most coarsely ribbed species of *Paryphoceras*, represented by several specimens figured by Waagen and Spath, which the Yemeni examples resemble closely. It is difficult to be certain whether the small evolute holotype (Waagen, 1875: pl. 36, fig. 4) of *P. stephanoides* Spath really belongs to this species, but it may be a small microconch, adult at 65–70 mm

diameter. The holotype of *P. cocosiforme* Spath (1931: pl. 115, fig. 1; received by Spath after his main description of *Paryphoceras*) is also strikingly like the Yemeni specimens, but differs slightly in the presence of about six single ribs amongst the 35 primary ribs on its outer whorl. These Cutch specimens occur in the Middle and Upper Oxfordian (Transversarium and Bimammatum Zones).

OCCURRENCE. Base of the Billum Member, Naifa Formation, Jebel Billum andAl Ma'abir; Bimammatum Zone, Upper Oxfordian.

Ammonites in the Madbi Formation

Poorly preserved ammonites occur in all three Storm Beds in the Madbi Formation. They are rare in the Middle Storm Bed, from which only three very poor fragments were obtained; two, CA1286–87, are indeterminate Perisphinctids, but the third, CA1183 (Pl. 7, fig. 3), is probably a *Peltoceratoides*, indicating a Lower Oxfordian age. Ammonites are found somewhat more commonly in the Upper Storm Bed, and eight fragments, CA1288–95, were obtained in sizes of up to 45 mm whorl height; several have the quadrate whorl section and straight primary ribs bifurcating at the ventro-lateral edge characteristic of *Perisphinctes* s.s. (Pl. 5, fig. 3). They could well belong species from the Plicatilis to Bifurcatus Zones of the Middle and Upper Oxfordian. All came from the outcrop 1 km east of the road, south of the river crossing at Al Ma'abir. A small *Laevaptychus* (CA839, from an Aspidoceratid), was obtained from the Lower Storm Bed in the Madbi Formation in central Jebel Billum. This meagre evidence suggests that the Madbi Formation is of approximately Lower, Middle and possibly basal Upper Oxfordian age.

Superfamily **PERISPHINCTACEAE** Steinmann, 1890, p. 441
Family **PERISPHINCTIDAE** Steinmann, 1890
Subfamily **PERISPHINCTINAE** Steinmann, 1890

REMARKS. *Torquatisphinctes – Pachysphinctes – Katroliceras* is one of the last lineages of this subfamily, which takes it into the Hybonotum Zone, Lower Tithonian. The work of Callomon (1981: 123, 149), Verma & Westermann (1984: 37–47) and Krishna & Pathak (1993: 229) suggests that this is a well-documented lineage of Tethyan Perisphinctinae, which is distinct from the more involute, tabulate and interrupted venters of most Idoceratinae, and from the virgatotome ribbing of the Ataxioceratidae (including the Virgatosphinctinae).

Genus ***LARCHERIA*** Tintant, 1961

TYPE SPECIES. *Larcheria larcheri* Tintant, 1961.

REMARKS. The genus *Larcheria* consists of the more involute, discoidal and multiplicate Perisphinctids that appear in the upper half of the Middle Oxfordian Transversarium Zone. *L. larcheri*, *L. schilli* (Oppel) and their allies are confined to that horizon in southern Europe (Atrops & Melendez, 1993; Melendez & Fontana, 1992), but *L. gredingensis* (Wegele, 1929) and *L. dorni* Tintant (1961: 137) are found in the Upper Oxfordian Bimammatum Zone in the Franconian Alb, associated with *Orthosphinctes polygyratus* (Reinecke) (Cariou & Hantzpergue, 1997: 85). The Yemeni specimens are identified with this younger group of species of *Larcheria.*

Larcheria gredingensis (Wegele, 1929) Pl. 3, figs 4, 5

1929 *Perisphinctes gredingensis* Wegele: 49, pl. 1, fig. 7.

MATERIAL. Four specimens: three, CA823–25, 7–8 m above the base of the Billum Member at the Perisphinctid Cliff near the eastern end of Jebel Billum (additionally a photograph of another specimen was taken in the field); and CA1088 from the basal part of the Billum Member about 1 km east of the Al Ma'abir road/river crossing.

DESCRIPTION. All are crushed flat laterally, three being about 120 mm diameter, the fourth (from the Al Ma'abir locality) is 80 mm diameter. The whorls are slightly involute, and the whorl section appears to have been compressed originally. Long, straight, prorsiradiate primary ribs bifurcate or trifurcate on the outer half of the whorl, and they do not diminish in strength up to the largest sizes seen. The ratio secondaries/primaries is 2.5–2.7/1.

REMARKS. These ammonites are more involute and have finer ribs than *Orthosphinctes polyplocus* with which they occur. One of the figured specimens (Pl. 3, fig. 4) is a very close match for Wegele's (1929: pl. 1, fig. 7) holotype from the Bimammatum Zone in Franconia, southern Germany. Another species from the same horizon in Franconia is *L. dorni* Tintant (1961: 137; *nom. nov.* for Dorn, 1930: 144, pl. 7, fig. 5), which is more involute and more densely ribbed than *L. gredingensis*.

OCCURRENCE. Lowest 5–8 m of the Billum Member, Naifa Formation, Jebel Billum and Al Ma'abir; Bimammatum Zone, Upper Oxfordian.

Genus ***ORTHOSPHINCTES*** Schindewolf, 1925

TYPE SPECIES. *Ammonites tiziani* Oppel, 1863 (=*Nautilus polygyratus* Reinecke, 1818).

REMARKS. Atrops (1982: 47–62) used the subgenus *Orthosphinctes (Orthosphinctes)* for microconchs corresponding to the macroconch subgenus *O. (Lithacosphinctes)*. They occur in the Bimammatum, Planula and base of the Platynota Zones, and follow the last of the many forms of *Perisphinctes* and its subgenera in the Transversarium and Bifurcatum Zones. The sequence of species was refined in the synthesis of Atrops & Melendez (1993: 22–26): *Orthosphinctes polygyratus* first occurs in the Bimammatum Zone (Bimammatum Subzone), where it is associated with *Larcheria gredingensis* (Wegele), then it occurs again in the bottom subzone of the Platynota Zone at the base of the Lower Kimmeridgian (Cariou & Hantzpergue, 1997: 85, 89).

The Yemeni examples of *Orthosphinctes* are not well-preserved and dimorphs cannot be identified (though at 250 mm or more in diameter some are almost certainly fragments of macroconchs), but their presence confirms the Bimammatum Zone date at the bottom of the Billum Member that is indicated by *Larcheria, Euaspidoceras* and the Mayaitids *Epimayaites* and *Paryphoceras* at the same horizon.

Orthosphinctes polygyratus (Reinecke, 1818)
Pl. 3, figs 7, 8

1818 *Nautilus polygyratus* Reinecke: 73, pl. 5, figs 45, 46.
1863 *Ammonites tiziani* Oppel: 246.
1877 *Ammonites (Perisphinctes) polygyratus* (Reinecke); Loriol: 61, pl. 7, fig.1.
1929 *Perisphinctes tiziani* (Oppel); Wegele: 44, pl. 1, figs 4, 5.
1935 *Planites* aff. *polygyratus* (Reinecke); Spath: 209, pl. 25, fig. 5.
1961 *Perisphinctes (Orthosphinctes) polygyratus* (Reinecke); Geyer: 21, pl. 1, fig. 4.
1961 *Perisphinctes (Orthosphinctes) tiziani* (Oppel); Geyer: 19, pl. 1, fig. 2; pl. 2, fig. 1; pl. 6, fig. 3.

1961 *Lithacoceras (Progeronia) pseudopolyplocoides* Geyer: 33, pl. 8, fig. 3.
1974 *Perisphinctes (Orthosphinctes) polygyratus* (Reinecke); Schairer: 51, pl. 6, figs 1–11.
1982 *Orthosphinctes (Orthosphinctes) polygyratus* (Reinecke); Atrops: 51, pls 11–14; pl. 16, figs 1, 3.

TYPE. A neotype from White Jura lower γ (base of Platynota Zone, Lower Kimmeridgian) at Randen, northern Switzerland, was figured by Geyer (1961: pl. 1, fig. 4).

MATERIAL. 41 specimens from the lower part of the Billum Member: 20 (C.86956–60, CA1089–1102, SM F.13413) from the bottom 5 m of the Billum Member, 1 km NE of the Al Ma'abir road/river crossing; 19 (CA826–35, and 9 photographs taken in the field) 7–8 m above the base of the Billum Member at the Perisphinctid Cliff in eastern Jebel Billum; two, CA836, 896, from west Jebel Billum, near the western entrance road cutting.

DESCRIPTION. All specimens are crushed and fragmentary to some degree. They range up to 150 mm diameter, but three fragments that have whorl heights of 80–85 mm must have been 250–275 mm diameter. The whorls are evolute, and the whorl section is elliptical with slightly flattened sides. Strong, slightly prorsiradiate primary ribs become more widely spaced on larger whorls. They divide into two or three secondaries high on the side of the whorl, then pass over the venter projected gently forwards but with no interruption. The ratio secondary/primary ribs is 2.4–2.7/1. Occasional constrictions follow the line of the ribs.

REMARKS. Schairer (1974: 51–56) had a much more extensive synoymy for *Orthosphinctes polygyratus*, into which he placed many other species as synonyms. His interpretation of the species was wider than that of Geyer (1961: 21), as can be seen in the range of morphology in the 11 specimens that he figured (Shairer, 1974: pl. 6, figs 1–11). This is not the place to discuss the detailed synonymy of the species, though it is worth noting that Schairer was probably correct in including the type species of *Orthosphinctes* (*Ammonites tiziani* Oppel, 1863) as a synonym, because comparison of the two type specimens (Geyer, 1961: pl. 1, fig.4 is the neotype of *Ammonites polygyratus*; Wegele, 1929: pl. 1, fig. 4, is the lectotype of *Ammonites tiziani*) shows them to be almost identical in all respects. Good specimens of *O. polygyratus* cannot be obtained from the lower part of the Billum Member – at all localities they are flattened and often seen only as external moulds on large slabs of hard limestone. Photographs taken in the field are the only record of some specimens, but they show the evolute whorls and primary ribs becoming more widely spaced at larger sizes, by which they differ from the more involute, more densely ribbed examples of *Larcheria* at the same horizon.

OCCURRENCE. Lowest 8 m of the Billum Member, Naifa Formation, Jebel Billum and Al Ma'abir; Bimammatum Zone, Upper Oxfordian.

Genus ***TORQUATISPHINCTES*** Spath, 1923a, p. 302 [1924a, p. 15]

TYPE SPECIES. *Ammonites torquatus* J. de C. Sowerby, 1840.

REMARKS. Due to its small size and indifferent preservation, interpretation of the holotype of the type species (refigured by Spath, 1931: pl. 76, fig. 4) is difficult. It could be an incomplete microconch or the inner whorls of a macroconch. It does, however, have some distinctive features: each of the prorsiradiate constrictions is followed by a simple, undivided rib, where growth increases segmentally. It is possible to relate this holotype to much larger ammonites, such as the undoubted microconch (possibly complete at 210 mm diameter) figured by Spath (1931: pl. 76, fig. 1) as the holotype (BM C.52470) of *T. jurunensis*. This has identical features to the *T. torquatus* holotype, despite Spath's (1931: 488) claims that *T. jurunensis* has sharper ribbing and is more densely ribbed (*T. jurunensis* is an internal mould; *T. torquatus* is a cast of an external mould on which the ribs are much more rounded; the rib densities are the same at the same diameter). So it is possible to interpret *Torquatisphinctes* as a genus with subquadrate, evolute whorls, with radial or slightly prorsiradiate primary ribs, most of which bifurcate; the rib before each constriction trifurcates; and each constriction is followed by a single rib, where the whorl size increases segmentally. It was found to be a useful genus by Krishna & Pathak (1993: 229), who described species from the Divisum up to the Beckeri Zones in Cutch, where they appear to be the ancestors of *Pachysphinctes* in the Eudoxus and Beckeri Zones.

Torquatisphinctes naifaensis sp. nov. Pl. 2, figs 1, 2

HOLOTYPE. CA974, 13.5 m above the base of the Kilya Member, Naifa Cliff.

PARATYPES. Three: CA975–76 are from the same horizon and locality as the holotype; the third is SM F.12168, from the Breadloaf Concretions in the lower part of the Kilya Member, east side of Wadi Arus.

OTHER MATERIAL. Fragments of four specimens, CA977–80, were obtained from the same horizon and locality as the holotype.

DIAGNOSIS. Evolute whorls, with strong, straight, radial primary ribs, mostly bifurcating at the ventro-lateral edge. Growth is somewhat segmental at the 3–4 constrictions per whorl.

DESCRIPTION. The holotype is preserved solid on one side, but is slightly crushed on the other; it has a final septum at 65 mm diameter, then a body-chamber 280° long, and is 110 mm diameter at its aperture, where the mouth-border is probably present on one side; it is probably a near-adult microconch. The whorls are evolute and serpenticone, and circular in cross-section. Most of the strong, straight, radial primary ribs bifurcate at the ventro-lateral position. There are a few single ribs, most immediately following the 3–4 constrictions per whorl, and the rib before each constriction has a third secondary that branches off the primary low down on the side of the whorl before the main bifurcation; the single rib following each constriction is angled further forwards, and the growth of the whorl increases segmentally at this point. Rib-density is fairly low – 51 ribs per whorl at 109 mm diameter, 44 at 66 mm, 40 at 47 mm, 39 at 33 mm. The paratypes from Naifa Cliff are both crushed flat; they are 63 mm and 55 mm diameter, and show all the features of the holotype, including the distinctive constrictions and low rib-densities. The paratype from Wadi Arus is an external mould of an uncrushed larger specimen, about 145 mm diameter, and shows the same features including the constrictions; it has 53 ribs per whorl at 138 mm diameter, and 52 at 105 mm diameter; suture-lines are not visible on casts made from this mould.

MEASUREMENTS

	D	Wh	Wb	U
CA974, holotype	104.0	30.0 (0.29)	26.3 (0.25)	53.0 (0.51)
CA974, holotype	64.0	17.4 (0.27)	17.2 (0.27)	33.8 (0.53)
C.24959, *T. torquatus* holotype	63.0	21.5 (0.34)	22.4 (0.36)	28.3 (0.44)

REMARKS. *T. naifaensis* is the most serpenticone and coarsely ribbed species of *Torquatisphinctes*, being more evolute and having fewer ribs than *T. torquatus*. The distinctive constrictions and segmental growth are well seen 5–6 ribs before the aperture and the coarse ribs are especially prominent on the inner whorls. Its Beckeri Zone age is derived from its association with other ammonites in the lower part of the Kilya Member.

OCCURRENCE. Lower marly part of the Kilya Member, Naifa Cliff and Wadi Arus; Beckeri Zone, Upper Kimmeridgian.

Genus ***KATROLICERAS*** Spath, 1924a

TYPE SPECIES. *Ammonites pottingeri* J. de C. Sowerby, 1840.

Katroliceras formosum Spath, 1931

Pl. 2, figs 3, 6; Pl. 4, figs 1–3, 5

1931 *Torquatisphinctes tenuistriatus* var. *formosa* Spath: 486, pl. 95, figs 4a, 4b.
?1931 *Pachysphinctes bathyplocus* (Waagen), var. *sparsiplicata* Spath: 495, pl. 78, figs 6a, 6b.
?1959 *Pachysphinctes bathyplocus* (Waagen), var. *sparsiplicata* Spath; Collignon: pl. 118, fig. 447.
?1959 *Torquatisphinctes torquatus* (Sowerby), var. *belamboensis* Collignon: pl. 118, fig. 448.
?1959 *Torquatisphinctes transitorius* Collignon: pl. 120, fig. 453.
?1959 *Katroliceras sowerbyi* Spath; Collignon: pl. 122, fig. 459.
?1959 *Katroliceras bassae* Collignon: pl. 124, fig. 466.
?1984 *Katroliceras*? cf. *bathyplocus* (Waagen); Verma & Westermann: 44, pl. 5, figs 2a, 2b.

MATERIAL. 33 specimens, CA1104–36, from the upper marly part of the Kilya Member in Wadi Kilya. They include 9 microconchs, 9 macroconchs and 14 fragments or specimens too small to be identified as microconchs or macroconchs.

DESCRIPTION. *Microconchs*. 6 adults have mouth-borders at 76, 71, 61, 51, 50 and 46 mm diameter, and body-chambers 0.7–0.8 whorls long. Microconchs become adult at a size before the distinctive depressed whorls and widely spaced primary ribs of *Katroliceras* are developed. The primary ribs are modified, however, on the final quarter whorl, becoming much more widely spaced, and all show slight uncoiling of the umbilical seam and decrease of the whorl breadth at the aperture. No lappets are preserved.

Macroconchs. All 9 are incomplete, but two attain diameters of 98 and 96 mm, one being septate up to 95 mm diameter, indicating a size of at least 130 mm diameter when complete. Whorls become depressed and primary ribs widely spaced from about 70 mm diameter. Macroconchs generally have slightly more massive whorls than microconchs of the same size, though separation is generally not possible below 40 mm diameter.

In both dimorphs the whorls are evolute and the whorl section is rounded-quadrilateral, varying between square and slightly depressed, but becoming more depressed from 70 mm diameter in the macroconch. Ribs on the inner whorls are straight, prorsiradiate or slightly curved forwards, and relatively fine and dense; most bifurcate regularly at the ventro-lateral angle, but occasional ribs remain single; from 50 mm diameter primary ribs become increasingly widely spaced, some are triplicate or multiplicate, and there are occasional intercalated secondary ribs; density of the ribs on the venter shows considerable variation; about 3 shallow constrictions per whorl are present on most specimens.

MEASUREMENTS

	D	Wh	Wb	U
CA1106, macroconch	95.5	23.6 (0.25)	28.6 (0.30)	49.8 (0.52)
CA1104, macroconch	94.5	27.2 (0.29)	29.3 (0.31)	49.0 (0.52)
CA1105, macroconch	71.0	21.0 (0.30)	24.2 (0.34)	34.3 (0.48)
CA1108, microconch	72.0	19.8 (0.28)	22.8 (0.32)	36.0 (0.50)
CA1107, microconch	65.5	19.3 (0.29)	21.0 (0.32)	33.5 (0.51)
CA1109, microconch	63.0	17.0 (0.27)	—	31.3 (0.50)

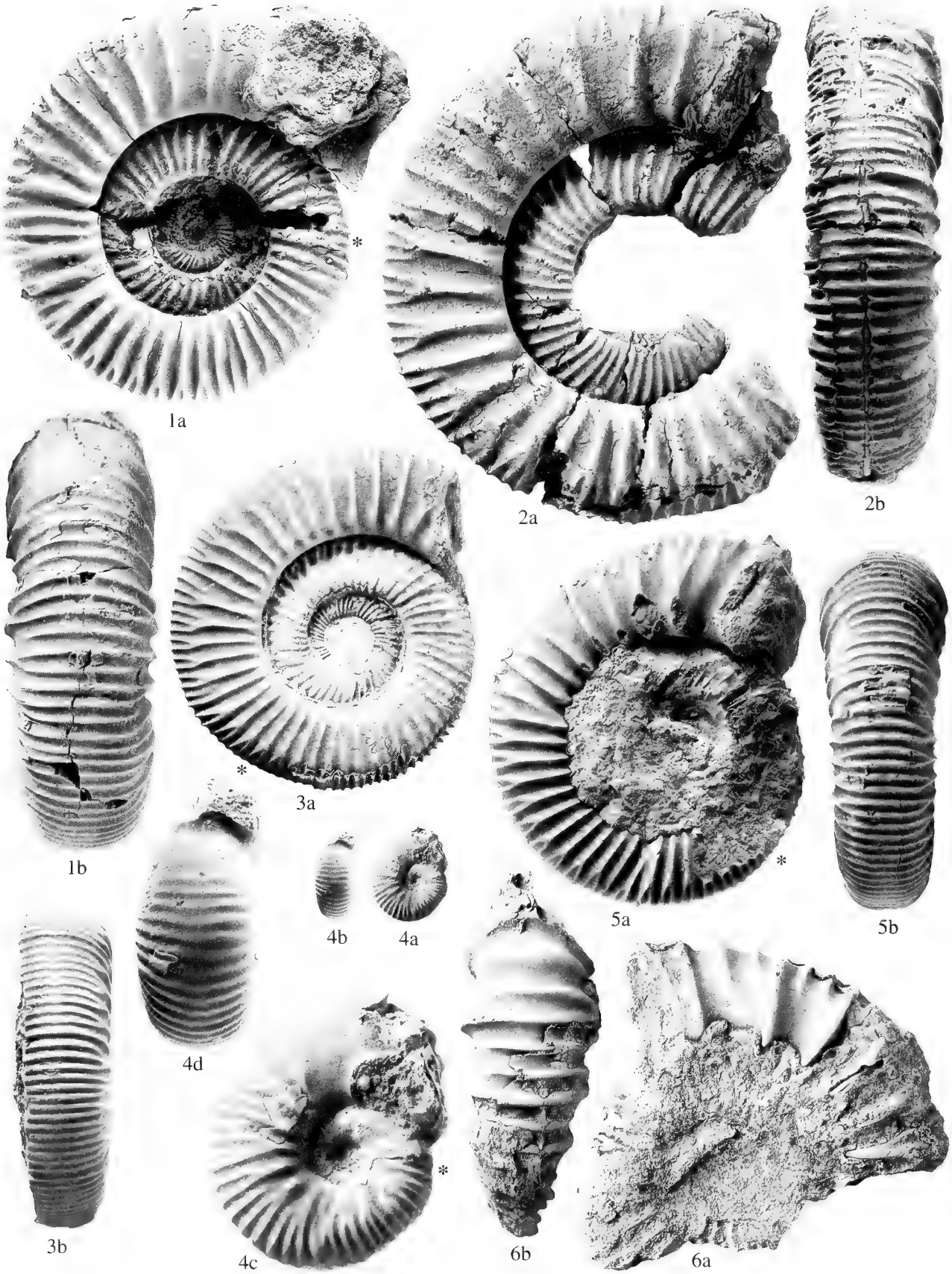
REMARKS. Amongst the many examples of *Katroliceras* figured by Waagen (1875), Futterer (1894), Spath (1931), Collignon (1959) and Verma & Westermann (1984), only a few are close to this Yemeni species, of which the distinctive features are the fine-ribbed, prorsiradiate, inner whorls and the quadrate, slightly depressed whorl section. The specimen from the Hybonotum Zone of Cutch figured by Spath (1931: pl. 95, fig. 4) as *Torquatisphinctes tenuistriatus* var. *formosa* is the closest match. The holotype of Spath's variety is 73 mm diameter and does not show adult features of either dimorph (the holotype of *Torquatisphinctes tenuistriatus* Spath (1931: pl. 85, fig. 1) has much more finely ribbed inner whorls). It is less certain that the holotype of Spath's (1931: pl. 78 fig. 6) variety *Pachysphinctes bathyplocus* var. *sparsiplicata* belongs to the same species because the inner whorls are less finely ribbed and distinctive and *Katroliceras* features are still not developed at 90 mm diameter. On the other hand, the four specimens from bed 525 in the Hybonotum Zone at Belambo, Manera, Madagascar, figured under four different names by Collignon (1959: figs 448, 453, 459, 466) are extremely similar to each other and to the Yemeni species. Finally, it is likely that Verma & Westermann's (1984: pl. 5, fig. 2) fine adult microconch (with a small lateral lappet) from the base of the Hybonotum Zone at Mombasa, Kenya, also belongs to this species, the only difference being its slightly less finely ribbed inner whorls. The multiplicity of specific names for *Katroliceras* will only be sorted out when collections from single horizons allow the amount of variation in a species to be discovered. Judging from the present collection from a single horizon in Yemen, such variation is only moderate, and is mainly in rib density, especially of the secondary ribs on the venter.

Complete microconchs are figured in Pl. 4, figs 1, 5, which show the rib modification at the aperture, though lappets are missing, while the microconch of Pl. 4, fig. 3 shows the fine-ribbed inner whorls well. The macroconchs of Pl. 2, fig. 3 and Pl. 4, fig. 2 show the broad depressed whorls and modified ribs that develop from 70 mm diameter, and Pl. 2, fig. 6 is an immature macroconch.

OCCURRENCE. The upper marly part of Kilya Member, Naifa Formation, Wadi Kilya; Hybonotum Zone, Lower Tithonian.

Katroliceras pottingeri (J. de C. Sowerby, 1840) Pl. 4, fig. 6

1840 *Ammonites pottingeri* J. de C. Sowerby: 719, pl. 61, fig. 10.
1875 *Perisphinctes pottingeri* (Sowerby); Waagen: 183, pl. 51, fig. 1.
?1875 *Perisphinctes katrolensis* Waagen: 184, pl. 103.
1894 *Perisphinctes pottingeri* (Sowerby); Futterer: 7, pl. 1, figs 1, 2.
1931 *Katroliceras pottingeri* (J. de C. Sowerby); Spath: 505, pl. 83, fig. 4; pl. 98, fig. 4; pl. 102, fig. 5.
1931 *Katroliceras waageni* Spath: 508 (*nom. nov.* for Waagen, 1875: pl. 51, fig.1).
?1931 *Katroliceras lerense* Spath: 511, pl. 89, fig. 1.
1959 *Perisphinctes pottingeri* (Sowerby); Collignon: pl. 121, figs 455, 456.
1959 *Perisphinctes pottingeri* (Sowerby), var. *analavalonensis* Collignon: pl. 121, fig. 457.


1a
2a
2b
1b
3a
5a
5b
4b
4a
4d
3b
4c
6b
6a

1959 *Katroliceras katrolense* (Waagen); Collignon: pl. 122, fig. 458.
1984 *Katroliceras pottingeri* (J. de C. Sowerby); Verma & Westermann: 42, text-fig. 5; pl. 4, fig. 1.

MATERIAL. One specimen, CA1137, from the upper marly part of the Kilya Member in Wadi Kilya.

DESCRIPTION. The single specimen is partly crushed, about 80 mm diameter, and has the middle part of the final whorl missing. At the aperture, part of the mouth-border can be seen where the shell thickness wedges out to nothing, and small portions of a suture-line are visible 290° earlier. The marked modification of the final three ribs and the contraction of the whorl breadth at the aperture suggest that it is an almost fully grown adult microconch, though there is no trace of a lappet. Primary and secondary ribs are coarse on the inner whorls, and become noticeably more widely spaced on the final quarter whorl, where the venter becomes broad and the whorl section depressed.

REMARKS. This probable near-complete adult microconch has much more coarsely ribbed inner whorls and is more depressed at the aperture than any of the specimens of *Katroliceras formosum* in the same bed in Wadi Kilya. It is closely similar to the best example of *K. pottingeri* figured previously, ie. Futterer's Mombasa specimen, which was splendidly refigured by Spath (1931: pl. 102, figs 5a, 5b – not figs 5c, 5d, which probably belongs to a different specimen), and reproduced in the *Treatise* (Arkell, 1957, fig. 425). Spath's figure appears to show the base of a lappet in the aperture, so it is an adult microconch complete at 85 mm diameter. The Yemeni specimen is a little smaller, and is slightly short of its final adult size. Compared with these, the Cutch holotype of *Katroliceras pottingeri*, refigured by Verma & Westermann (1984: 43, text–fig. 5), is very poorly preserved, and it is impossible to see suture-lines or judge its degree of completeness.

OCCURRENCE. Upper marly part of the Kilya Member, Naifa Formation, Wadi Kilya; Hybonotum Zone, Lower Tithonian.

Katroliceras sp. indet.

Fragments of about 45 specimens (including CA1138–44), all too fragmentary or too poorly preserved to be specifically identified, were obtained from the upper marly part of the Kilya Member in Wadi Arus. They could be examples of either *K. formosum* or *K. pottingeri*.

Genus ***SUBDICHOTOMOCERAS*** Spath, 1925

TYPE SPECIES. *Subdichotomoceras lamplughi* Spath, 1925.

Subdichotomoceras ?latissimum (Zwierzycki, 1914)
Pl. 2, fig. 5

?1914 *Perisphinctes latissimus* Zwierzycki: 65, pl. 8, fig. 4.
?1931 *Subdichotomoceras inversum* Spath: 521, pl. 84, fig. 7; pl. 85, fig. 4.
?1931 *Subdichotomoceras simplex* Spath: 522, pl. 83, fig. 8.
?1933 *Perisphinctes* cf. *sparsiplicatus* Waagen; Dietrich: 20, pl. 1, fig. 2.
?1959 *Subdichotomoceras diadema* Spath; Collignon: pl. 148, fig. 591.
?1959 *Subdichotomoceras mandaranense* Collignon: pl. 149, figs 597, ?598, ?599.
1984 *Subdichotomoceras* aff. *sparsiplicatum* (Waagen); Verma & Westermann: 47, pl. 5, fig. 1.

MATERIAL. One specimen, CA1145, from the upper marly part of the Kilya Member in Wadi Kilya.

DESCRIPTION. This is a well-preserved microconch consisting of half a whorl of uncrushed body-chamber ending at an adult mouth-border at 60 mm diameter. The whorl is evolute, and the whorl section slightly depressed as shown by the measurements below: those at 59 mm diameter were taken inside the collar immediately before the aperture, and the low values for whorl height and whorl breadth reflect the depth of that constriction, while those at 55.5 mm (where Wh and Wb are higher) are between the two major primary ribs before the constriction and give a better value of the depression of the whorl section. The strong, sharp primary ribs are regularly biplicate at the rounded ventro-lateral angle, except for a single rib angled more strongly forwards immediately before the final constriction. The secondary ribs are curved gently forwards on the venter without interruption. At the aperture a strong rib follows the constriction, then the shell is flared, and small portions of the mouth-border itself are preserved near the umbilicus and the mid-venter, but unfortuntely not on the side of the whorl where a lappet would be expected.

MEASUREMENTS

	D	Wh	Wb	U	Wh/Wb
CA1145	59.0	15.3 (0.26)	16.4 (0.28)	31.4 (0.53)	0.93
CA1145	55.5	15.6 (0.28)	18.6 (0.34)	29.5 (0.53)	0.84
CA1145	43.0	11.8 (0.27)	15.0 (0.35)	—	0.79

REMARKS. Most species and most figured specimens of *Subdichotomoceras* are more depressed than this Yemeni specimen, and it is difficult to find examples that are sufficiently evolute and have similar whorl proportions at the same diameter (ie. a whorl height/breadth ratio of 0.79–0.84 at 43–55 mm diameter). Thus one of the commonest Cutch species, *S. sparsiplicatus* (Waagen, 1875: 204, pl. 49, fig. 2; revised by Spath, 1931: 523, pl. 86, fig. 7; pl. 87, fig. 4; pl. 101, fig. 1) is consistently too depressed (Wh/Wb ratio of 0.67–0.7 at 70–86 mm diameter), though the ribbing is similar. There is little doubt that the highly evolute specimen from the Hybonotum Zone at Mombassa figured by Verma & Westermann (1984: pl. 5, fig. 1) as *S.* aff. *sparsiplicatum* (Waagen) (Wh/Wb ratio 0.89 at 114 mm diameter), belongs to the same species. Said to be almost complete at 114 mm diameter, with the mouth-border just missing, it is probably a microconch, especially when compared with macroconchs of *Subdichotomoceras* (eg. *S.* aff. *sparsiplicatum* (Waagen) of Verma & Westermann, 1984: pl. 6, fig. 3; pl. 7, figs 1, 2) that are larger, more involute and have higher whorls. Most *Subdichotomoceras* from the Lower Tithonian of Madagascar (Collignon, 1959: pls 148, 149, figs 591–599) are too involute or too depressed, though two (figs 591, 597) might be the same as the Yemeni specimen. Instead of proposing a new species based on only the Yemeni and the Verma & Westermann (1984: pl. 5, fig. 1) specimens, it seems better to identify them with *S. latissimus*

PLATE 4

Figs 1–3, 5 *Katroliceras formosum* Spath, upper marly part of Kilya Member (fauna 8), Wadi Kilya. **1a, 1b,** CA1108; **2A, 2b,** CA1106, wholly septate; **3a, 3b,** CA1109; **5a, 5b,** CA1107.
Fig. 4 *Sutneria weidmanni* Zeiss, Breadloaf Concretions, Kilya Member (fauna 7), east cliff, Wadi Arus. **4a-4d,** SM F.12162; 4a, 4b, ×1; 4c, 4d, ×3.
Fig. 6 *Katroliceras pottingeri* (J. de C. Sowerby), upper marly part of Kilya Member (fauna 8), Wadi Kilya. **6a, 6b,** CA1137.

(Zwierzycki, 1914: 65, pl. 8, fig. 4), from the Lower Tithonian of Tendaguru, Tanzania. Zwierzycki's only figured specimen is similarly evolute and has the same pattern and density of ribs, but is only 33 mm maximum diameter, and has depressed whorls with a Wh/Wb ratio of 0.61 at 30 mm diameter. Another small example was figured by Dietrich (1933: pl. 1, fig. 2), who recorded several others from the *Smeei* and *Nerinella* Beds at Tendaguru. Many ammonites (including *Subdichotomoceras*) become less depressed at larger sizes, so the same species might be represented at Cutch by the two much larger specimens given the names *S. inversum* and *S. simplex* by Spath (1931: pl. 83, fig. 8; pl. 84, fig. 7; pl. 85, fig. 4). They have quadrate, only slightly depressed whorls (Wh/Wb ratio of 0.87–0.90 at 105–120 mm diameter), the same sharp regularly biplicate ribs, and both appear to be macroconchs. Whatever specific name is given to these ammonites from Yemen, Cutch, Mombasa, Tendaguru and Madagascar, they are all from the Hybonotum Zone and are good evidence for the age of the beds in which they occur.

OCCURRENCE. Upper marly part of Kilya Member, Naifa Formation, Wadi Kilya; Hybonotum Zone, Lower Tithonian.

Genus ***SUTNERIA*** Zittel, 1884

TYPE SPECIES. *Nautilus platynotus* Reinecke, 1818.

SYNONYM. *Enosphinctes* Schindewolf, 1925; type species, *Sutneria subeumela* Schneid, 1914.

Sutneria weidmanni Zeiss, 1979 Pl. 2, fig. 4; Pl. 4, fig. 4

1979*Sutneria weidmanni* Zeiss: 271, abb. 3, figs 19, 20; abb. 4.

MATERIAL. Seven specimens, CA721–25 and SM F.12162, F.12163, from the Breadloaf Concretions in the Kilya Member, east side of Wadi Arus.

DESCRIPTION. Five specimens have parts of their adult mouth-borders preserved at 24.7, 22.0, 21.0, 19.0 and 17.0 mm diameter, including lappets in four of them; the other two are small inner whorls of 11.5 mm and 10 mm diameter, the latter being so highly depressed and cadicone that it is only doubtfully referred to *Sutneria*. There is a marked constriction, especially in whorl breadth, immediately before the mouth-border, then a flared rostrum on the venter and small, triangular, pointed lappets on the side of the whorl; the length of the lappet is approximately half the whorl height. The adult body-chambers are 0.6–0.8 whorls long. The whorls are involute and depressed (Wh/Wb = 0.81–0.94 at 15–23 mm diameter), and the whorl section is smoothly rounded with no angles at umbilical or ventro-lateral edges. The ornament consists of straight, near-radial primary ribs that divide at the middle of the whorl side into two or three secondaries; occasional ribs on the inner whorls divide into four or five secondaries, and such multiple divisions are usually achieved by successive bifurcations. There are 14–15 primary ribs per whorl at 15–17 mm diameter. A small mid-lateral tubercle, sometimes elongated radially, occurs at some of the primary bifurcation points. The ribs tend to fade just before the adult mouth-border.

MEASUREMENTS

	D	Wh	Wb	U
SM F.12162	15.3	6.4 (0.42)	7.6 (0.50)	4.4 (0.29)
SM F.12163	16.7	7.3 (0.44)	7.8 (0.47)	4.4 (0.26)
CA721	23.3	8.9 (0.38)	10.7 (0.46)	6.3 (0.27)
CA722	20.6	8.1 (0.39)	9.8 (0.48)	5.6 (0.27)
CA723	20.1	7.9 (0.39)	9.7 (0.48)	6.1 (0.30)

REMARKS. *Sutneria weidmanni* Zeiss was based on two specimens from Ali Sabieh, Djibouti, found in association with ammonites determined by Prof. Dr A. Zeiss (*in* Conrad, Peybernes & Weidmann, 1975: 19) as *Aspidoceras freneixae* Collignon, *A. bertucati* Collignon, *Pachyplanulites* (?) cf. *irregularis* Spath and *Subplanites* aff. *spathi* Venzo. The age was given as Eudoxus Zone (ie. the upper half of Zeiss's (1971: 536, table 1; 1979: 276) 'Middle Kimmeridgian'). The Yemeni specimens are a close match for Zeiss's (1979: abb. 3, figs 19, 20) holotype, and the best preserved of them (Pl. 4, fig. 4) has a complete mouth-border with lappet on one side. In fact four of the Yemeni specimens have lappets, which are not preserved in either of the Djibouti originals, and they show that the size range of complete adults was at least 17–25 mm diameter. *Sutneria weidmanni* is somewhat more involute and has more depressed and thicker whorls than many species of *Sutneria*. It is characterized by its thick depressed whorls and its birfurcating to quadrifurcating primary ribs that bend only gently backwards on the outer half of the whorl side. It is a species of the group leading to *S. subeumela* Schneid that has been referred to the subgenus *S. (Enosphinctes)* by some authors (Geyer, 1963: 189; 1969: 65, fig. 1).

OCCURRENCE. Lower part of Kilya Member, Naifa Formation, east side of Wadi Arus; Beckeri Zone, Upper Kimmeridgian.

Genus ***PACHYSPHINCTES*** Dietrich, 1925

TYPE SPECIES. *Perisphinctes (Pachysphinctes) africogermanus* Dietrich, 1925, subsequently designated by Spath (1930: 42).

REMARKS. *Pachysphinctes* is an East African – Indian Ocean genus, characterized by evolute, square to massive whorls and strong ribs. Species have been recorded and described from Tanzania by Müller (1900), Zwierzycki (1914) and Dietrich (1925; 1933), from Kenya by Futterer (1894), Spath (1930) and Verma & Westermann (1984), from Ethiopia by Venzo (1959) and Zeiss (1971), from Somalia by Spath (1925; 1935), from Cutch by Waagen (1875) and Spath (1931), and from Madagascar by Collignon (1959). Some species attain very large sizes and have massive final whorls – a *Pachysphinctes muelleri* (Burckhardt) (BMHN collection) collected by the author and Dr Noel Morris in 1965 in the Mandawa anticline in southern Tanzania is 1095 mm diameter and has a very massive, but incomplete, body-chamber with the following measurements: at 1095 mm diameter: 330 (0.30), 320 (0.29), 498 (0.46). While that specimen must be a macroconch, some of the largest known microconchs also occur in *Pachysphinctes*, eg. those from Cutch figured by Spath (1931: pl. 77, fig. 1; pl. 97, fig. 1; pl. 98, fig. 5) which are 165 mm and 175 mm diameter at their lappetted mouth-borders. Some of the species in East Africa were revised by Verma & Westermann (1984: 37–41) who examined the type material of the type species, *P. africogermanus* from southern Tanzania, and designated the 75 mm diameter original of Dietrich (1925: pl. 1, fig. 2) as lectotype. They (Verma & Westermann, 1984: 39–41, text-fig. 4) also refigured the largest of Futterer's (1894: pl. 2, fig. 1) figured syntypes of *P. beyrichi* from Mombasa (this is not the lectotype as Verma & Westermann stated, because the smaller original of Futterer, 1894, pl. 2, fig. 2, had already been designated lectotype by Spath (1930: 55)). Both these East African species have fairly fine, biplicate ribs, and whorls that appear to become massive at large sizes. An even more finely ribbed species from Tanzania is *P. mahokondo-beyrichi* (Dietrich, 1925: 13, pl. 3, fig. 5).

Specimens similar to, or identical with, *P. beyrichi* occur commonly in Cutch, where a second species is more evolute, has massive depressed whorls, and coarser ribs. Waagen (1875: 191–193) pointed out the difficulties in distinguishing between the two at small sizes,

because distinctive characters are only attained at diameters well in excess of 100 mm. These two species are the commonest *Pachysphinctes* in southern Yemen, and after consideration of the difficult problems of nomenclature, they are described below as *Pachysphinctes bathyplocus* (Waagen) (of which *P. beyrichi* (Futterer) is probably a synonym) and *P. major* Spath. A few, more finely ribbed specimens are described as *P. mahokondobeyrichi* (Dietrich).

As pointed out by Verma & Westermann (1984: 38), excessive splitting of both genera and species by Spath (1931) in his revision of the Cutch fauna, make it likely that many of his new species are minor variants of *P. bathyplocus* and *P. major*, and some of the probable synonymies are indicated below, though proper revision must await the availability of single horizon collections from Cutch. The Yemeni collections of *Pachysphinctes* from single horizons at Naifa Cliff and Al Ma'abir show a moderate amount in variation in whorl proportions and rib-density, that is certainly sufficient to embrace several of Spath's species at Cutch.

INTERPRETATION OF CUTCH *PACHYSPHINCTES*. Waagen described two common species from the Middle Katrol Beds of Cutch, which he identified as *Perisphinctes torquatus* (J. de C. Sowerby) (Waagen, 1875: 191, pl. 54) and *P. bathyplocus* sp. nov. (Waagen, 1875: 192, pl. 50, fig. 1). In redescribing these two species, Spath (1931: 466) noted that it was very difficult to identify the large example of Waagen's pl. 54 with the much smaller holotype of Sowerby's *Ammonites torquatus*, which he refigured (Spath, 1931: pl. 76, fig. 4), so he proposed the replacement name *Pachysphinctes major* Spath (1931: 467, 489) for Waagen's pl. 54 and other specimens that were available to Waagen and himself. As Spath did not designate a holotype, the original of Waagen's pl. 54 is here designated lectotype of *P. major*. Spath had that lectotype on loan, and after examining it he wrote 'Waagen's large example [ie. Waagen, pl. 54] is entirely septate and the suture-lines are quite distinct in various places on the outer whorl, so his remarks about the lobes not being visible must be due to a slip' (that remark was 'The lobes are not visible on any part of the specimens at hand' (Waagen, 1875: 192)). Again, in his redescription of Waagen's species *P. bathyplocus*, Spath (1931: 493) wrote 'Waagen's description was based largely on specimens other than the figured type'. Spath also had the original of Waagen's pl. 50, fig. 1 on loan (BM C.52480 is a plaster-cast), and he was alluding to the many differences between Waagen's descriptions and the single specimens that he figured to illustrate the two species. Spath did not claim, however, that the two figured specimens or their captions had been transposed at some stage, even though there is a clear precedent for such a mistake in Waagen's (1875) monograph (the labels and captions of his plates 40 and 41 were transposed, as is abundantly clear when text and plates are compared, as was pointed out by Spath (1931: 374), who described it as 'the wrong numbering of Waagen's plates'). The case for the transposition of the captions of Waagen's pl. 50, fig. 1 and pl. 54 is less clear: his description of *P. bathyplocus* is of a species that develops massive depressed whorls and large coarse primary ribs at sizes larger than 150 mm diameter, which together with his measurements of a 210 mm diameter specimen, fit the example figured in pl. 54. The original of pl. 50, fig. 1 is a better match for his description of *Perisphinctes torquatus*, though that 133 mm diameter figured specimen is not one of the three for which he gave measurements. Though transposition of the figured specimens or their captions is highly suggestive, the case remains unproved, and rather than disrupt existing nomenclature, it has been decided to leave interpretation of the two species unchanged, ie. *Pachysphinctes bathyplocus* (Waagen) is based on its lectotype, Waagen, 1875, pl. 50, fig. 1, and *P. major* Spath is based on its lectotype, the original of Waagen's pl. 54. [To reverse the identity of these two lectotypes would mean applying the name *P. bathyplocus* to pl. 54, of which *P. major* would then become an objective synonym (ie. based on the same type specimen), and it would leave pl. 50, fig. 1 without a Waagen or Spath name, for which *P. beyrichi* (Futterer) would become available].

OCCURRENCE. Tanzania, Kenya, Ethiopia, Somalia, Yemen, western India (Cutch), Madagascar; occurs in the Beckeri (Upper Kimmeridgian) and Hybonotum (Lower Tithonian) Zones, though there is some evidence that *P. beyrichi* (=*P. bathyplocus* here) first occurs slightly lower, in the Eudoxus Zone in Kenya (Verma & Westermann, 1984: 40).

Pachysphinctes bathyplocus (Waagen), 1875

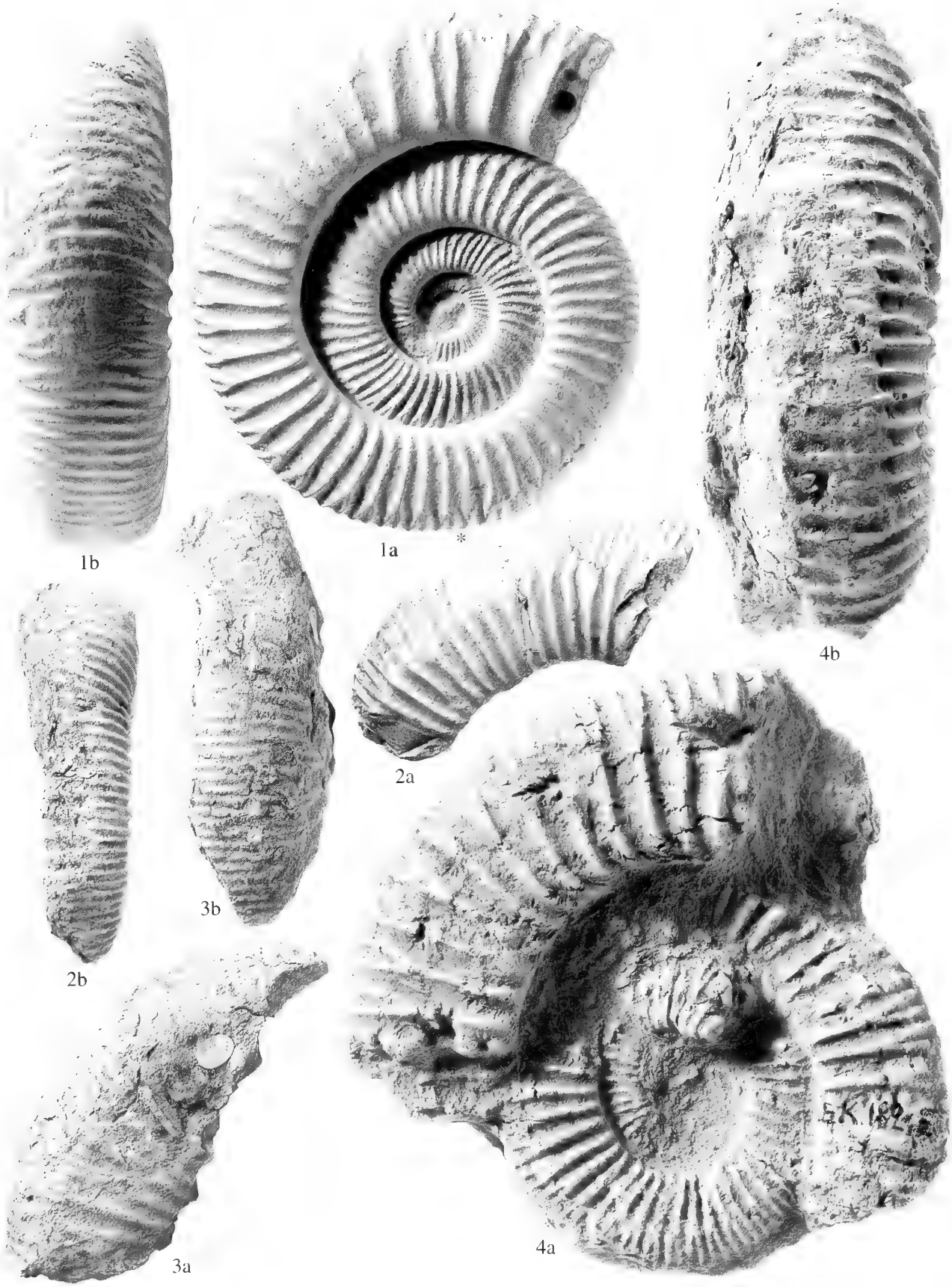
Fig. 2; Pl. 5, figs 1, 4; Pl. 7, figs 2, 5

1875 *Perisphinctes bathyplocus* Waagen: 192, pl. 50, fig. 1.
1894 *Perisphinctes beyrichi* Futterer: 9, pl. 2, figs 1–3.
1910 *Perisphinctes (Virgatosphinctes?) beyrichi* Futterer; Dacqué: 14, pl. 4, fig. 2.
?1910 *Perisphinctes africanus* Dacqué: 17, pl. 3, fig. 2.
1925 *Perisphinctes* cf. *biplicatus* Uhlig; Stefanini: 144, pl. 27, fig. 1.
?1925 *Perisphinctes (Pachysphinctes) africogermanus* Dietrich: 12, text–figs 1, 2, pl. 3, fig. 1 (*non* fig. 2).
1930 *Torquatisphinctes beyrichi* (Futterer); Spath: 55, pl. 3, fig. 6.
1931 *Pachysphinctes granti* Spath: 492, pl. 90, fig. 6.
1931 *Pachysphinctes bathyplocus* (Waagen); Spath: 493, pl. 77, fig. 1; pl. 78, fig. 6; pl. 88, fig. 1; pl. 93, figs 5, 9; pl. 96, fig. 4.
1931 *Pachysphinctes wantraensis* Spath: 497, pl. 95, fig. 1.
?1931 *Pachysphinctes symmetricus* Spath: 498, pl. 101, fig. 7.
?1931 *Pachysphinctes orientalis* Spath: 499, pl. 100, fig. 2.
1959 *Torquatisphinctes betsibokensis* Collignon: pl. 109, fig. 401.
1959 *Pachysphinctes granti* Spath; Collignon: pl. 116, fig. 443.
1959 *Pachysphinctes marellei* Collignon: pl. 117, fig. 444.
1959 *Pachysphinctes trichordis* Collignon: pl. 117, fig. 445.
1959 *Pachysphinctes bathyplocus* (Waagen), var. *sparsiplicata* Spath; Collignon: pl. 118, fig. 447.
?1959 *Torquatisphinctes adeloides* Spath; Collignon: pl. 127, fig. 475.
1984 *Pachysphinctes beyrichi* (Futterer); Verma & Westermann: 39, text–fig. 4, pl. 6, figs 1, 2.

LECTOTYPE. The original of Waagen, 1875, pl. 50, fig. 1, here designated, and refigured in Pl. 5, fig. 1.

MATERIAL. 37 specimens from the Kilya Member: 5, CA1147–51, from the upper marly part; CA1152 from the top bed of the middle limestone part, and 5, CA1153–56 and C.86964, from high in the same part in Wadi Kilya; 20, CA981–94, SM F.12195–97, F.12199, F.12203 and F.12205, from the bottom of the middle limestone part, in Naifa Cliff; 5, CA726–30 from the Breadloaf Concretions in the lower marly part in Wadi Arus, and CA995 from the same part in Naifa Cliff.

DESCRIPTION. Many of the 37 specimens referred to this species are parts of single whorls in the size range 100–200 mm diameter. Most are portions of body-chambers, and the largest fragment has a whorl height and breadth of 70 mm and 62 mm respecively, indicating a diameter of approximately 275 mm. There are no complete mouth-borders and no lappets or other evidence of microconchs. Inner whorls are evolute, with a depressed whorl section and rounded


1b
1a *
4b
2a
2b
3b
3a
4a

ventro-lateral angles and venter. From about 70 mm diameter the whorl section becomes typically quadrilateral or almost square, then above 150 mm diameter the whorls become more compressed but still retain the quadrate appearance. Primary ribs are of moderate density on middle and inner whorls, becoming slightly fewer and more distant beyond 150 mm diameter. Typical densities are 45–50 ribs per whorl up to 150 mm diameter, decreasing to 40–45 at larger sizes. Most ribs are sharply biplicate, a few remain single, and from 100 mm diameter there are a few extra secondary ribs. Ribs cross the venter radially and are slightly diminished along the mid-siphonal line. There are two or three oblique constrictions per whorl up to 150 mm diameter, which tend to disappear at larger sizes.

MEASUREMENTS

	D	Wh	Wb	U
C.52840 (cast), lectotype	133.0	34.4 (0.26)	36.5 (0.27)	73.2 (0.55)
P. beyrichi lectotype	71.0	21.0 (0.30)	24.8 (0.35)	32.7 (0.46)
P. beyrichi paralectotype	170.0	50.0 (0.29)	52.0 (0.31)	81.0 (0.48)
P. beyrichi paralectotype	60.0	19.8 (0.33)	25.0 (0.42)	27.0 (0.45)
CA982	148.0	39.0 (0.26)	43.0 (0.29)	77.5 (0.52)
CA995	220.0	56.0 (0.25)	51.5 (0.23)	110.0 (0.50)
CA985	—	70.0	62.0	—
CA986	—	64.0	55.0	—

REMARKS. A plaster-cast of the Cutch lectotype is figured in Pl. 5, fig. 1 for comparison with Waagen's (1875: pl. 50, fig. 1) drawing. At 136 mm maximum diameter, it is clearly an incomplete microconch, because it compares exactly with similar-sized parts of a complete Cutch microconch figured by Spath (1931: pl. 77, fig. 1), which has a mouth-border and large lappets at 165 mm diameter. Compared with these and the many other Cutch specimens listed in the synonymy, the examples from Yemen are mostly fragments, but at least the collection contains parts of large body-chambers of macroconchs (Pl. 7, fig. 5), which are presumably near-adult at their largest sizes, which indicate diameters of 275–300 mm. Such macroconch body-chambers, with compressed quadrate whorls and ribs of moderate size and density, are very different from the massive depressed whorls of *P. major* macroconchs that have very large and thick primary ribs. The differences between the two species are very clear in macroconchs, but microconchs are much less distinct, having ribs of similar size and density, and it is only at diameters of 100 mm or more that the whorl breadth of *P. major* becomes sufficiently large to provide a reliable distinction from *P. bathyplocus*. A more complete macroconch, though still seriously defective in preservation, is figured in Fig. 2; it has at least half a whorl of body-chamber and an incomplete aperture at 235 mm diameter. The small inner whorls from Naifa Cliff figured in Pl. 7, fig. 2, are closely similar to the Cutch lectotype.

The lectotype of *Perisphinctes beyrichi* Futterer (1894: pl. 2, fig. 2) from Mombasa, Kenya, and other specimens figured by Verma & Westermann (1984) do not appear to differ from *Pachysphinctes bathyplocus* in any feature worthy of specific separation, ie. whorl proportions, rib-densities (at 75 mm diameter there are 45 ribs in Futterer's lectotype, 47 in Waagen's lectotype) and styles of ribbing are almost identical. Specimens from East Africa are known only to diameters of 170 mm, at which size the distinctive compressed whorl section of *P. bathyplocus* is not fully developed. Six specimens from the Hybonotum (? and Beckeri) Zones of Madagascar were figured under six different names by Collignon (1959) (see synonymy). They exhibit all the typical characters of *P. bathyplocus*, and four of them (Collignon, 1959: figs 444, 445, 447, 475) are from the same bed and locality.

OCCURRENCE. Lower, middle and upper parts of the Kilya Member, Naifa Formation, Wadi Kilya, Naifa Cliff and Wadi Arus; Beckeri Zone, Upper Kimmeridgian and Hybonotum Zone, Lower Tithonian.

Pachysphinctes major Spath, 1931

Pl. 6, figs 1, 2; Pl. 7, fig. 1; Pl. 8, fig. 2

1875 *Perisphinctes torquatus* (J. Sowerby); Waagen: 191, pl. 54.
1925 *Perisphinctes* cf. *linki* Choffat; Stefanini: 145, pl. 27, fig. 2.
1931 *Pachysphinctes major* Spath: 489, pl. 75, fig. 1; pl. 78, figs 1, 2; pl. 87, fig. 3; pl. 89, fig. 6.
1931 *Pachysphinctes robustus* Spath: 491, pl. 84, fig. 5; pl. 93, fig. 10.
1931 *Pachysphinctes crassus* Spath: 492, pl. 85, fig. 3.
1931 *Pachysphinctes linguiferus* Spath: 496, pl. 97, fig. 1; pl. 98, fig. 5.
1959 *Pachysphinctes linguiferus* Spath; Collignon: pl. 118, fig. 446.
1959 *Pachysphinctes major* Spath; Collignon: pl. 119, fig. 449.
1959 *Pachysphinctes robustus* Spath; Collignon: pl. 120, fig. 451.

LECTOTYPE. The original of Waagen, 1875, pl. 54, here designated.

MATERIAL. 46 specimens from the Kilya Member: 5, CA1157–61 from the upper marly part, 11, CA1162–71 and C.86962 from the upper part of the middle limestone part, CA1172–73 from the base of the same part, all in Wadi Kilya; 23, CA996–1016, SM F.12194a and F.12204, from the base of the middle limestone part in Naifa Cliff; 5, CA731–34 and SM F.12167 from the Breadloaf Concretions in the lower marly part of the Kilya Member in the east cliff of Wadi Arus.

DESCRIPTION. Many of the 46 specimens referred to this species are fragments of body-chambers of 150–200 mm diameter, though there are a few much larger, more complete specimens. The largest is 420 mm diameter and consists of a massive body-chamber 320° long from the last septum at about 250 mm diameter, but the final mouth-border is missing. On inner whorls the whorl section is slightly depressed, then becomes much more depressed and massive from 150 mm diameter. Primary ribs are sharp, mostly biplicate and of moderate density (42–50 per whorl) up to 100–150 mm diameter, and there are a few single and triplicate ribs. From 150 mm diameter the primary ribs become much more widely spaced and bold, finally

PLATE 5

Figs 1, 4 *Pachysphinctes bathyplocus* (Waagen). **1, lectotype**, Middle Katrol beds, Katrol Range, Cutch, India (figured Waagen, 1875, pl. 50, fig. 1), BM C.52480 (plaster-cast), ×0.75. **4a, 4b,** base of middle limestone part of Kilya Member (fauna 7), Naifa Cliff, SM F.12196, wholly septate.

Fig. 2 *Pachysphinctes mahokondobeyrichi* (Dietrich), base of middle limestone part of Kilya Member (fauna 7), Naifa Cliff, CA1017.

Fig. 3 *Perisphinctes (Perisphinctes)* sp. indet., Upper Storm Bed, Madbi Formation (fauna 3), 1 km east of road, south of river crossing at Al Ma'abir, CA1288, ×0.72.

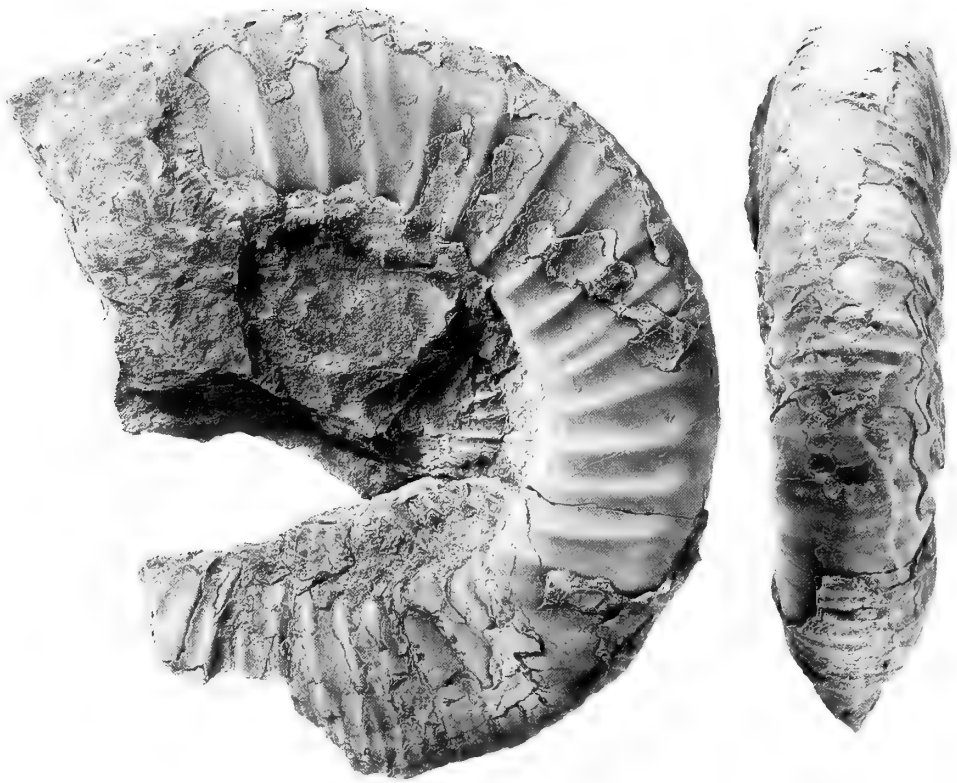


Fig. 2 *Pachysphinctes bathyplocus* (Waagen), 16.5 m above base of lower marly part of Kilya Member (fauna 7), Naifa Cliff; CA995, ×0.5.

ending as very large wedge-shaped radial ridges at the largest sizes, so that rib densities as low as 18 primary ribs per whorl occur at 400 mm diameter. When the primary ribs start to increase in size and strength, three to five secondary ribs are associated with each primary, either by multiple splitting or intercalation. As size increases the association between primaries and secondaries becomes less clear, then the secondaries gradually disappear so that the venter becomes broad and smooth from 225–250 mm diameter. One to three oblique constrictions on inner whorls tend to disappear beyond 150 mm diameter.

MEASUREMENTS. In ammonites it is traditional to measure whorl breadth in the inter-costal space between ribs, rather than across the tops of the ribs themselves. In a species like *P. major* that has very heavy ribs at large sizes, such a measurement of whorl breadth makes the whorls appear much less depressed than when the measurement is taken across the tops of the ribs. In the measurements below an extra figure is given for the whorl breadth across the tops of the ribs (WbR) which better illustrates the real amount of whorl depression.

	D	Wh	Wb	WbR	U
Lectotype (from Waagen)	210.0	57.0 (0.27)	—	74.0 (0.35)	103.0 (0.49)
Lectotype (from pl. 54)	210.0	59.0 (0.28)	—	66.0 (0.31)	104.0 (0.50)
CA1170	420.0	97.0 (0.23)	100.0 (0.24)	129.0 (0.31)	242.0 (0.50)
CA1170	310.0	77.5 (0.25)	93.0 (0.30)	105.0 (0.34)	—
CA1171	277.0	75.0 (0.27)	75.0 (0.27)	87.0 (0.31)	143.0 (0.52)
CA998	310.0	74.0 (0.24)	89.0 (0.29)	99.0 (0.32)	—
CA1005	235.0	66.0 (0.28)	63.0 (0.27)	70.0 (0.30)	120.0 (0.51)
CA1157	187.0	49.5 (0.26)	63.0 (0.34)	68.0 (0.36)	100.0 (0.53)
CA1014	108.0	31.5 (0.29)	35.0 (0.32)	—	54.0 (0.50)

REMARKS. The largest specimen figured hitherto is Waagen's (1875: pl. 54) lectotype, which is still septate at its aperture at 210 mm diameter (*test* Spath, 1931: 489), at which size the massive whorls and heavy ribs are not fully developed. The typical characters of the species are well seen in the very large 420 mm diameter Yemeni macroconch (CA1170) figured in Pl. 8, fig. 2, which seems to be the largest example found so far. It is, of course, much smaller than the largest known *Pachysphinctes*, which is the 1095 mm diameter *P. muelleri* from Tanzania, briefly described above (p. 50). At 420 mm diameter the ribs of CA1170 are very large, and are of such high relief that the ratio of whorl height/whorl breadth measured across the tops of the ribs (97 mm:129 mm = 0.75) is much lower than the same ratio (97 mm:100 mm = 0.97) when the whorl breadth is measured in the inter-costal space. Slightly greater whorl depression (ratio 0.74) is shown at 310 mm diameter in the same specimen where the whorl height and breadth are 77.5 and 105 mm respectively. Even these large whorls are not as depressed as the

PLATE 6

Figs 1, 2 *Pachysphinctes major* Spath. **1a, 1b,** upper marly part of Kilya Member (fauna 8), Wadi Kilya, CA1157, ×0.66. **2a, 2b,** base of middle limestone part of Kilya Member (fauna 7), Naifa Cliff, CA1014.

1a

1b

2a

2b

fragment that Waagen (1875: 193) said had a whorl height and breadth of 65 mm and 100 mm respectively (ratio 0.65), from which it has to be concluded that Waagen measured the whorl breadth across the tops of the ribs. The example in Pl. 6, fig. 1, though roughly preserved, is figured to show that coarse ribs and depressed whorls can develop much earlier, here from about 125 mm diameter, and thereafter such specimens differ greatly from *P. bathyplocus*. Coming from the upper, marly part of the Kilya Member in Wadi Kilya, of Hybonotum Zone age, it is from the youngest horizon of ammonites in the Naifa Formation. Inner whorls of *P. major* are figured in Pl. 6, fig. 2, to show the close resemblance at these sizes to *P. bathyplocus*, and in this example the large whorl thickness is at least partly due to the distortion caused by preservation in a septarian nodule. There are no clear microconchs amongst the Yemeni collection, but a fine Cutch microconch with lappets at 175 mm diameter was figured by Spath (1931: pl. 97, fig. 1: pl. 98, fig. 5). Collignon (1959: pl. 118, fig. 446) had another microconch complete at 161 mm diameter amongst the three specimens (Collignon, 1959: figs 446, 449, 451) that he figured under three different names, even though all came from the same bed and locality in the Hybonotum Zone in Madagascar. It is the same bed from which came the four examples of *P. bathyplocum* referred to above, and shows that as in southern Yemen, the two species occur together at the same horizon.

OCCURRENCE. Lower, middle and upper parts of the Kilya Member, Naifa Formation, Wadi Kilya, Naifa Cliff and Wadi Arus; Beckeri Zone, Upper Kimmeridgian and Hybonotum Zone, Lower Tithonian.

Pachysphinctes mahokondobeyrichi (Dietrich, 1925)

Pl. 5, fig. 2; Pl. 8 fig. 5

1925 *Perisphinctes (Virgatosphinctes) mahokondobeyrichi* Dietrich: 13, pl. 3, fig. 5.

LECTOTYPE. The original of Dietrich, 1925, pl. 3, fig. 5, here designated.

MATERIAL. Five specimens, CA1017 and SM F.12190–93, from the base of the middle limestone part of the Kilya Member in Naifa Cliff.

DESCRIPTION. All five specimens are fragments of body-chambers, the largest having a whorl height of 37 mm, indicating a diameter of approximately 140 mm. The whorls are quadrate and slightly depressed. Dense primary ribs mostly bifurcate at the ventro-lateral edge, and occasional ones trifurcate. No fragment is long enough to count the number of ribs per whorl or per half whorl, but ribs are more dense than in similar-sized examples of *P. bathyplocus*, suggesting a rib-density in the range 55–60 per whorl at 100 mm diameter.

REMARKS. *P. mahokondobeyrichi* is the identification given to examples of *Pachysphinctes* that have whorl proportions similar to *P. bathyplocus*, but are more densely ribbed. Dietrich (1925: 13, pl. 3, fig. 5) quoted rib densities of 45 per whorl at 50 mm diameter and 63 per whorl at 95 mm diameter (though counting on his figure (which is a retouched photograph) gives densities of 51 at 46 mm and 64 or 65 at 93 mm diameter), and the Yemeni specimen appears to fall within this range. In other respects they do not differ from *P. bathyplocus*.

OCCURRENCE. Base of the middle limestone part of the Kilya Member, Naifa Formation, Naifa Cliff; Beckeri Zone, Upper Kimmeridgian.

Pachysphinctes sp. indet.

MATERIAL. Many crushed ammonites occur in a shell bed near the top of the Kilya Member in Naifa Cliff and parts of 15 specimens (CA1019–33) were collected. A few others come from high in the middle limestone part (CA1174–80) of the same member in Wadi Kilya. Most belong to *Pachysphinctes bathyplocus* or *P. major*, but they are not specifically identifiable due to the crushing. They are of Beckeri Zone age.

Subfamily **IDOCERATINAE** Spath, 1924
Genus ***IDOCERAS*** Burckhardt, 1906

TYPE SPECIES. *Ammonites balderus* Oppel, 1863, subsequently designated by Spath (1925: 129) (not Roman, 1938).

REMARKS. Spath's designation of *Ammonites balderus* Oppel as the type species of *Idoceras* is derived from his declaration 'the true *Idoceras* of the *balderum* group' (Spath, 1925: 129), followed immediately by his proposal of the new generic name *Subnebrodites* for *Ammonites planula* Zieten, 1830. By these means the top Oxfordian–Lower Kimmeridgian, evolute, coarse ribbed species of *Subnebrodites* were separated from the Upper Kimmeridgian (Tethyan), involute, more finely ribbed species of *Idoceras*, and it is to the latter genus that most of Burckhardt's (1906, 1912) and Imlay's (1939) Mexican forms belong. The separation of the two genera was not accepted by Ziegler (1959), but given the amount of morphological difference, and the stratigraphical separation, it seems to be a useful distinction and was accepted by Callomon (1981: 149, 151). The Yemeni material of *Idoceras* described here includes only poor and fragmentary examples from Wadi Hajar (though one is very large), but there are two good specimens from another area 200 km to the west.

Idoceras ahwarense sp. nov. Pl. 8, figs 1, 3; Pl. 11, fig. 1

TYPES. The holotype is C.71097 and the paratype is C.71098, both from Ghanam al Kuffar (13°45'N, 46°41'E), in Wadi Ahwar, 30 km north of Ahwar and 36 km north of the mouth of Wadi Ahwar on the coast of the Gulf of Aden.

OTHER MATERIAL. SM F.12164, from the Breadloaf Concretions in the Kilya Member, in the east cliff of Wadi Arus, and CA837, found loose at the base of the Billum Member at the Perisphinctid Cliff in eastern Jebel Billum, having fallen from a higher horizon.

DIAGNOSIS. A large involute species of *Idoceras*, reaching at least 200 mm diameter in macroconchs. Whorl section compressed, whorl sides nearly flat, rounded umbilical and ventro-lateral edges; narrow, nearly flat venter, with a slight central depression. Ribs are strong throughout growth; primary ribs straight and radial, some

PLATE 7

Fig. 1 *Pachysphinctes major* Spath, base of middle limestone part of Kilya Member (fauna 7), Naifa Cliff, CA1010, body-chamber, ×0.66.

Figs 2, 5 *Pachysphinctes bathyplocus* (Waagen), base of middle limestone part of Kilya Member (fauna 7), Naifa Cliff. **2a, 2b,** CA981, body-chamber, ×0.69; **5a, 5b,** CA985, body-chamber, ×0.66.

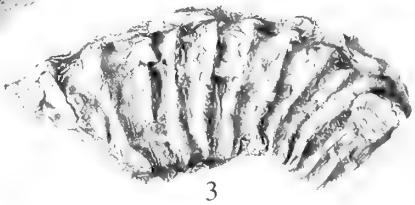
Fig. 3 *Peltoceratoides* sp. indet. Middle Storm Bed, Madbi Formation (fauna 2), 1 km east of road, south of river crossing at Al Ma'abir, CA1183.

Fig. 4 *Idoceras* cf. *balderum* (Oppel), Breadloaf concretions, Kilya Member (fauna 7), east cliff, Wadi Arus, CA735, body-chamber.

1a

1b

2a



3

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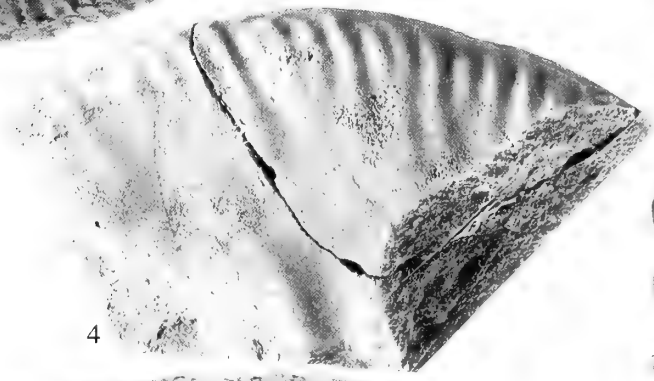


4

5a

5b

2b


1a
*
1b
2b
2a
*
3b
3a
4a
4c
4b
5a
5b

bifurcating near the ventro-lateral border; secondary ribs form forwardly pointing chevrons on the venter, where there is a marked mid-ventral interruption.

DESCRIPTION. The holotype is the phragmocone of a macroconch, still septate at its aperture at 125 mm diameter; it must have been at least 200 mm diameter when complete with 270° of adult body-chamber. The paratype is a microconch, septate up to 47 mm diameter, and then has 270° of body-chamber up to its aperture at 72 mm diameter; it has no adult features. SM F.12164 is an immature microconch; it consists of inner whorls, half of which are missing on one side; the smaller end of the outer whorl is septate, the larger end is not septate, but the position of the last septum cannot be seen; in addition a short portion of the final whorl up to an apparently complete plain mouth-border at 46 mm diameter is attached to these inner whorls. CA837 is a short fragment of a whorl, of about 50 mm whorl height, that closely matches the largest part of the holotype. The whorls are involute, flat sided and compressed, and the microconchs have a slightly larger umbilicus than the macroconch (see Measurements). The ribs are straight, radial and approximately half bifurcate near the ventro-lateral edge, though the proportion that bifurcate increases with size. The holotype has 53 ribs per whorl at 120 mm diameter, and 50 at 80 mm; the paratype has 51 ribs at 68 mm. The number of primary/secondary ribs per half whorl is 26/44 at 117 mm diameter in the holotype, and 27/40 at 68 mm in the paratype. The secondary ribs swing forwards to form chevrons on the venter and are interrupted along the mid-ventral line. One or two poorly developed constrictions per whorl occur up to about 35 mm diameter.

MEASUREMENTS

	D	Wh	Wb	U
C.71097	120.0	47.2 (0.39)	28.3 (0.29)	41.2 (0.34)
C.71097	70.0	25.3 (0.36)	17.7 (0.25)	24.3 (0.35)
C.71098	66.7	23.9 (0.36)	16.3 (0.24)	26.8 (0.40)
SM F.12164	31.1	11.1 (0.36)	9.5 (0.31)	11.8 (0.38)

REMARKS. This new species belongs to the younger, involute, true *Idoceras* rather than to the older, evolute, often more strongly ribbed *Subnebrodites*. One of the closest species morphologically is *Idoceras farquharsoni* Spath (1935: 213, pl. 24, fig. 1) from the Kimmeridgian of Somalia, which also retains its ribs up to the largest size seen (104 mm diameter), but it has much finer (ca. 70 ribs/whorl at 100 mm diameter), prorsiradiate, curved primary ribs, which bifurcate lower on the side of the whorl than in *I. ahwarense*. Neither species shows the fading of the ribs on the side of the whorls that is characteristic of *I. balderum* (Oppel). The numerous species of *Idoceras* in Mexico described by Burckhardt (1906: 38–66; 1912: 101–127) and Imlay (1939: 37–41) all differ in whorl proportions or ornament, many being more evolute or tending to become smooth on the side of the whorl. Many species of *Idoceras* are dimorphic, the microconchs being noticeably more evolute, with slight uncoiling of the umbilical seam towards the end of the adult body-chamber, but only a few (and none of the Yemen or east African specimens) are preserved with rib modifications and a deep terminal constriction followed by a blunt lappet at the mouth-border, as in *I. mexicanum* Burckhardt (1906: pl. 11, fig. 11) and better developed in *Subnebrodites* (Zeigler, 1959: pl. 1, fig. 6).

The small Wadi Arus microconch is from the Breadloaf Concretions and shows that the age of *I. ahwarense* is Beckeri Zone. The type specimens from Wadi Ahwar are well-preserved and mostly uncrushed, but are from an unrecorded horizon; it can only be surmised that latter is also in the Kilya Member of the Naifa Formation. They were obtained by an amateur collector in October 1962.

OCCURRENCE. Lower part of the Kilya Member, Naifa Formation, Wadi Arus and Wadi Ahwar; Beckeri Zone, Upper Kimmeridgian.

Idoceras cf. *balderum* (Oppel, 1863) Pl. 7, fig. 4

1863 *Ammonites balderus* Oppel: 242, pl. 67, fig. 2.
1878 *Ammonites (Perisphinctes) balderus* Oppel; de Loriol; 94, pl. 15, fig. 7 (*non* fig. 8).
1929 *Idoceras balderum* (Oppel); Wegele: 78, pl. 9, fig. 7.
1959 *Idoceras balderum* (Oppel); Ziegler: 25, fig. 1a; pl. 1, figs 3, 4.

MATERIAL. One specimen, CA735, from the Breadloaf Concretions in the Kilya Member in the east cliff of Wadi Arus.

DESCRIPTION. This fragment is a quarter of a whorl of body-chamber, preserved solid, but mainly on one side only, though the whole of the width of the venter is exposed. The whorl height at the larger end is 56 mm, indicating a diameter of approximately 150 mm. The radial ribs have faded over much of the side of the whorl, leaving large undulations at the umbilical edge, and secondary ribs near the ventro-lateral edge, which are projected forwards to form chevrons on the venter, then interrupted at mid-venter.

REMARKS. Although it compares closely with the largest part of the example figured by Ziegler (1959: pl. 1, fig. 3), this specimen is only compared with *I. balderum* on account of its fragmentary nature. In southern France and Germany *I. balderum* characterizes a subzone of the Divisum Zone at the top of the Lower Kimmeridgian.

OCCURRENCE. Kilya Member, Naifa Formation, Wadi Arus; Beckeri Zone, Upper Kimmeridgian.

Idoceras cf. *hararinum* Venzo, 1942 Fig. 3; Pl. 9, fig. 1

1942 *Idoceras hararinum* Venzo: 48, pl. 6, fig. 8; pl. 7, figs 2–4; pl. 13, fig. 3.
?1943 *Ringsteadia africana* Scott: 64, pl. 10, figs 1, 2.
1954 *Idoceras hararinum* Venzo; Valduga: 21, fig. 7; pl. 5, fig. 3.
1959 *Idoceras hararinum* Venzo; Venzo: 151, pl. 6, fig. 8; pl. 7, figs 2–4; pl. 12, fig. 3.

MATERIAL. One specimen, CA1034, from the base of the middle limestone part of the Kilya Member, Naifa Cliff. Another specimen of 450–500 mm diameter was seen at the same horizon and locality, but could not be collected.

DESCRIPTION. The single ammonite is a very large complete body-chamber, 320° long, 475 mm diameter at the mouth-border, and approximately 270 mm diameter at the end of the phragmocone. It is

PLATE 8

Figs 1, 3 *Idoceras ahwarense* sp. nov. **1a, 1b, paratype**, Ghanam al Kuffar (13°45'N, 46°41'E), Wadi Ahwar, 30 km north of Ahwar and 36 km north of the mouth of Wadi Ahwar on the coast of the Gulf of Aden, C.71098. **3a, 3b,** Breadloaf concretions, Kilya Member (fauna 7), east cliff, Wadi Arus, SM F.12164.

Fig. 2 *Pachysphinctes major* Spath, upper part of middle limestone part of Kilya Member (fauna 7), Wadi Kilya, CA1170, ×0.36.

Fig. 4 *Nebrodites hospes* (Neumayr), Breadloaf Concretions, Kilya Member (fauna 7), east cliff, Wadi Arus. **4a-c,** CA736.

Fig. 5 *Pachysphinctes mahokondobeyrichi* (Dietrich), base of middle limestone part of Kilya Member (fauna 7), Naifa Cliff, SM F.12192.

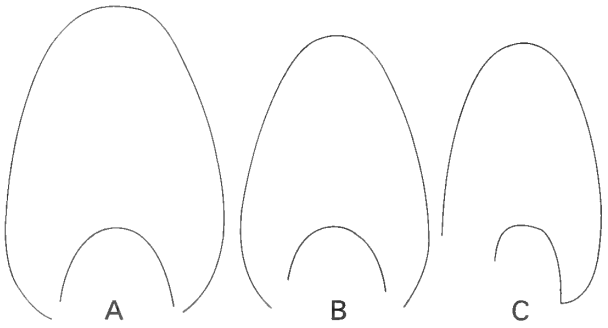


Fig. 3 *Idoceras* cf. *hararinum* Venzo, whorl cross-sections of CA1034 of Pl. 9, fig. 1; A, at 128 mm whorl height and about 430 mm diameter; B, at 114 mm whorl height and 320 mm diameter; C, at 100 mm whorl height and 270 mm diameter; all ×0.35.

mostly preserved solid, being slightly crushed on parts of the outer side of the whorl. The shell immediately adjacent to the mouth-border is crushed, except for the ventral rostrum which is intact, and the short part of the end of the phragmocone is crushed. The whorl section has a smoothly rounded umbilical wall and edge and an evenly rounded venter. The sides of the whorl converge strongly towards the venter and the greatest whorl breadth is a quarter to a third of the whorl height from the umbilical seam. The venter of the previous whorl can be seen at five breaks in the body-chamber (Fig. 3); it is evenly rounded like the venter of the body-chamber, but on the smallest visible cross-section the inner whorl (ie. about 1.8 whorls before the mouth-border, at a diameter of approximately 140 mm) has a narrower rounded venter and flatter sides, like that of a more compressed *Idoceras*. Small portions of the final septum are also visible here, attached to the outside of the venter of the inner whorl. The shell is visible at several places on the body-chamber, and is completely smooth, with no trace of any ornament. Measurements of CA1034: at 460 mm diameter: 135 (0.29), 97 (0.21), 215 (0.47).

REMARKS. This very large body-chamber closely resembles the largest of Venzo's (1959: pl. 7, fig. 2) figured specimens, which is here designated lectotype. That specimen is 280 mm diameter, and appears to be a complete adult macroconch with 0.75 whorls of body-chamber. It has traces of forwardly angled secondary ribs on the venter at the end of the phragmocone, 0.8 whorls before the aperture, and appears to become smooth from the beginning of the body-chamber. The Yemen specimen is almost exactly one whorl larger, the end of its phragmocone being the same size as the mouth-border of the lectotype, so its complete lack of ornament agrees with the lack of ornament on the lectotype at the same size. Up to about 150 mm diameter *Idoceras hararinum* has ribs that are fairly coarse, but typical of *Idoceras*, as can be seen on the figured paralectotypes (Venzo, 1959: pl. 6, fig. 8; pl. 7, fig. 3).

The age of *I. hararinum* in Ethiopia is a problem: Venzo (1959: 186, 190) referred it to the Tenuilobatum Zone (covering the whole of the Lower Kimmeridgian), but his distribution tables show that at Diredaua it is associated with many other ammonites, including *Pachysphinctes*, *Katroliceras* and *Simaspidoceras*. If they are all of the same age, the present evidence from Yemen suggests that this age cannot be older than the upper half of the Eudoxus Zone and is more probably Beckeri Zone. The other three localities in Ethiopia at which *I. hararinum* occurs, all of which were referred to the Tenuilobatum Zone by Venzo, do not contain other ammonites from which age evidence can be deduced. Of even more interest at Diredaua is the presence of a single specimen (the holotype) of an ammonite described as *Ringsteadia daua* Scott (1943: 65, pl. 11, figs 1, 2). Also, two ammonites from Dogou and one from Ganame were made the types of another new species of *Ringsteadia*, *R. africana* Scott (1943: 64, pl. 10, figs 1, 2). Scott referred all these specimens to the uppermost Oxfordian, an age assessment that was quoted by Arkell (1956: 314) as giving 'an exceptionally precise correlation with the topmost zone of the Oxfordian of NW Europe'. The Ethiopian '*Ringsteadia*' have all the morphological characters of large *Idoceras*: the holotype of '*R.*' *africana* (Scott, 1943: pl. 10, figs 1, 2) has secondary ribs forming chevrons on the venter which disappear at about 200 mm diameter, then the whorls are smooth; it is septate to 215 mm diameter, and has one quarter of a whorl of body chamber up to 240 mm diameter; it would have been about 300 mm diameter when complete with three-quarters of a whorl of body-chamber. In fact Scott's figure of that holotype bears such a close resemblance to the lectotype of *I. hararinum*, when compared at the same size, that it is likely that the two ammonites are conspecific. '*R.*' *daua* might also be the same: it is difficult to judge from Scott's figure, but the description of the ornament is like that of *Idoceras*. Other perisphinctids from the same localities in Ethiopia, especially *Perisphinctes vokesi* Scott (1943: pl. 10, figs 3, 4) and *P. spathi* Scott (1943: pl. 13, figs 2, 4), could well be examples of *Pachysphinctes*, or other genera that occur in the top of the Kimmeridgian (Eudoxus and Beckeri Zones) and not earlier. This Ethiopian fauna seems to have placed too low in the zonal sequence.

OCCURRENCE. Middle part of the Kilya Member, Naifa Cliff; Beckeri Zone, Upper Kimmeridgian.

Genus ***NEBRODITES*** Burckhardt, 1912

TYPE SPECIES. *Simoceras agrigentinum* Gemmellaro, 1872b, subsequently designated by Spath (1925: 130).

Nebrodites hospes (Neumayr, 1873) Pl. 8, fig. 4

1873 *Perisphinctes hospes* Neumayr: 185, pl. 39, fig. 3.
1875 *Ammonites doublieri* d'Orbigny; Favre: 34, pl. 4, fig. 2.
1876 *Ammonites sautieri* Fontannes: 294, pl. 16, fig. 1; pl. 17, fig. 1 (*non* pl. 18, fig. 1).
1877 *Ammonites (Perisphinctes) allobrogicus* Pillet; Favre: 50, pl. 5, fig. 4.
1877 *Ammonites (Simoceras) doublieri* d'Orbigny; Favre: 57, pl. 7, fig. 2 (*non* fig. 4).
1888 *Ammonites planula* Hehl; Quenstedt: 976, pl. 108, fig. 5.
1888 *Ammonites planula minor* Quenstedt: 976, pl. 108, fig. 8.
1888 *Ammonites* cf. *balderus* Oppel; Quenstedt: 978, pl. 108, fig. 12.
1893 *Hoplites guimaraesi* Choffat: 72, pl. 17, fig. 11.
1905 *Simoceras* cf. *malletianum* (Fontannes); Kilian & Guébhard:827, pl. 50, fig. 1.

PLATE 9

Fig. 1 *Idoceras* cf. *hararinum* Venzo, base of middle limestone part of Kilya Member (fauna 7), Naifa Cliff, CA1034, ×0.34.

Fig. 2 *Aspidoceras longispinum* (J. de C. Sowerby), base of middle limestone part of Kilya Member (fauna 7), Naifa Cliff. **2a, 2b,** CA1036, wholly septate.

Fig. 3 *Aspidoceras apeninnicum* Zittel, upper part of middle limestone part of Kilya Member (fauna 7), Wadi Kilya. **3a, 3b,** CA1192, ×0.66.


*
1
3b
2b
2a
*
3a

1905 *Simoceras* cf. *sautieri* (Fontannes); Kilian & Guébhard: 827, pl. 50, fig. 2.
1912 *Nebrodites haizmanni* Burckhardt: 89, pl. 22, figs 2–4.
1959 *Nebrodites (Nebrodites) hospes hospes* (Neumayr); Ziegler: 38, pl. 1, figs 15, 16.
1959 *Nebrodites (Nebrodites) hospes minor* (Quenstedt); Ziegler: 38, pl. 1, fig. 17.

MATERIAL. One specimen, CA736, from the Breadloaf Concretions in the Kilya Member in the east cliff of Wadi Arus. Several examples were seen in a bed of shell debris in the middle limestone part of the Kilya Member, in the section south of Wadi Kilya; though too fragile to be collected, two specimens were photographed in the field.

DESCRIPTION. The small specimen from Wadi Arus is an adult microconch. It is almost complete at its aperture at 40 mm diameter, where two large flared ribs are separated by a narrow constriction, and only the lappet is missing in the mouth-border. The whorls are evolute and quadrate. The ribs are straight and radial, a few bifurcate either at the umbilical edge or near the middle of the side of the whorl, then they pass onto the tabulate venter, which has a smooth central band. Several constrictions are present. The specimens photographed in Wadi Kilya were 125–150 mm diameter; they had similarly evolute whorls and parts of their body-chambers preserved.

REMARKS. Though species of *Nebrodites* are clearly dimorphic, macroconchs and microconchs have not been associated in the same described species. Many microconchs have been referred to the species *N. hospes* (Neumayr), which occurs in the Acanthicum Zone and lower half of the Eudoxus Zone in south-western Germany, where complete adults are 25–60 mm diameter. Several complete specimens were figured by Quenstedt (1888) and Ziegler (1959), while smaller (25–40 mm diameter) and more finely ribbed specimens were referred to *N. macerrimus* (Quenstedt; Ziegler, 1959: 40, pl. 1, fig. 18). The many very much larger macroconchs figured by Gemmellaro (1872b) and Ziegler (1959), that have plain mouth-borders without lappets, range up to 260 mm diameter. The inner whorls of some of these, eg. *N. peltoideus* and *N. cafisii* (Gemmellaro, 1872b: 154, 156, pl. 3, figs 5, 6 [pp. 47, 49, pl. 8, figs 5, 6 in the reprint]; Ziegler, 1959: 36, pl. 1, figs 10, 11), look to be identical with some examples of *N. hospes*, and it may be that the latter species is the microconch, and thus a junior synonym, of one of the earlier described Gemmellaro species. *N. cafisii* is one of the highest species to occur in south-west Germany, in White Jura δ4, in the upper half of the Eudoxus Zone, according to the records of Ziegler (1958a: 185; 1959: 36). The Yemeni specimens might belong to this species, and it might be necessary to extend its range (and that of the genus) into the Beckeri Zone on account of its association with other ammonites of that date in Yemen.

A specimen from the Mandawa-Kilwa area of southern Tanzania, of uncertain date in the Kimmeridgian, figured as *N. aethiopicoherbichi* Dietrich (1925: 14, pl. 2, fig. 2), has similar inner whorls, but has coarse widely spaced ribs on its outer whorl and belongs to the subgenus *Mesosimoceras*. A large fragment from Ethiopia referred to the same species by Venzo (1959: 157, pl. 8, fig. 1) is not determinable, and examples from north-west Madagascar were recorded by Besairie (1936: 64) but not figured. These are the nearest occurrences of *Nebrodites* to southern Yemen.

OCCURRENCE. Lower and middle parts of the Kilya Member, Wadi Arus and Wadi Kilya; Beckeri Zone, Upper Kimmeridgian.

Family **PACHYCERATIDAE** Buckman, 1918
Genus ***ERYMNOCERAS*** Hyatt, 1900

TYPE SPECIES. *Ammonites coronatus* Bruguière, 1789.

Subgenus ***PACHYERYMNOCERAS*** Breistroffer, 1947

TYPE SPECIES. *Pachyceras jarryi* Douvillé, 1912.

Erymnoceras (Pachyerymnoceras) jarryi (Douvillé, 1912)
Pl. 11, fig. 4

1912b *Pachyceras jarryi* Douvillé: 37, figs 37–43; pl. 1, figs 3–5, 7, 8, 10, 12.
?1970 *Erymnoceras (Pachyerymnoceras)* cf. *jarryi* (Douvillé); Imlay: D13, pl. 2, figs 1, 2.
1977 *Pachyceras (Pachyerymnoceras) jarryi* Douvillé; Charpy & Thierry: 206–208, figs 4D, 4E; pl. 3, figs 1, 2; pl. 5, figs 2, 3.
1983 *Pachyerymnoceras* cf. *jarryi* (Douvillé); Lewy: 26, figs 6B, 6H; pl. 4, fig.3.

MATERIAL. Three specimens: CA838 from 17 m below the top of the Upper Shuqra (ie. below the base of the Lower Storm Bed at the bottom of the Madbi Formation) and 6 m above the limestone containing large *Paracenoceras meridionale* Tintant in central Jebel Billum; CA1181 from a similar horizon in the Upper Shuqra, 1 km east of the road south of the Al Ma'abir river crossing; and CA1182 from the top part of the Middle Shuqra at the same locality.

DESCRIPTION. All three specimens are crushed and distorted to varying amounts. CA838 has slightly distorted phragmocone up to about 40 mm diameter, followed by three-quarters of a whorl of a more severely crushed body-chamber, and is probably complete at its aperture at 60 mm diameter. CA1181 has part or all of its body-chamber preserved, is 65 mm diameter, crushed laterally, and the ornament is fairly well seen. CA1182 is 80 mm diameter and is very rough and weathered, but probably has most of its body-chambers preserved; on account of its preservation it is best determined as *Erymnoceras (Pachyermnoceras)* cf. *jarryi*. The whorls are depressed and cadicone, with a funnel-shaped umbilicus, and an angled umbilical edge leading almost directly into a broad arched venter. The body-chambers might be less depressed, but it is difficult to see the original shape of the whorl section. Bold ribs issue in twos or threes from prominent tubercles on the umbilical edge, and a few of them branch again, or more ribs are intercalated, just above the tubercles. The ribs cross the venter radially or are angled slightly forwards, and diminish considerably along the mid-ventral line. There are 12–13 umbilical tubercles and 36–38 ribs on the venter of the final whorl of CA838.

REMARKS. Allowing for the distortion, the figured specimen (Pl. 11, fig. 4) is closely similar to Douvillé's (1912b: pl. 1, figs 10, 10a) holotype, which is an undistorted specimen from the Upper Callovian (probably Lamberti Zone) of Normandy. More specimens from this area, including a neotype, were figured by Charpy & Thierry (1977: pl. 5, fig. 2). Examples of *Pachyerymnoceras* from Jebel Tuwaiq, central Saudi Arabia, have been figured by Arkell (1952), Imlay (1970) and Enay *et al* (1987), and from Israel and Sinai by Lewy (1983) and Gill *et al* (1985). The varying amounts of distortion suffered by most specimens have led to different species classifications that are difficult to reconcile, eg. the Jebel Tuwaiq specimen figured by Imlay (1970: pl. 2, figs 1, 2), which is very like the Jebel Billum specimen, was referred to the new species *Pachyerymnoceras levantinense* by Lewy (1983: 25) on account of its sudden change to

a compressed body-chamber. The latter, however, is crushed laterally, and it may originally have had a whorl thickness like that of *P. jarryi*.

The age assessments of Gill *et al* (1985: 744) in Israel and Enay *et al* (1987: 36, 44) in Jebel Tuwaiq were based on the whole fauna of ammonites and they concluded that the main occurrence of *Pachyerymnoceras* is in the Middle Callovian, Coronatum Zone. There is no evidence for the presence of Upper Callovian in Jebel Tuwaiq, but it is possible that *Pachyerymnoceras* extends into the Upper Callovian, Athleta Zone, in Israel. Several specimens of *Pachyerymnoceras* from Ethiopia were described and figured by Zeiss (1974), and in the absence of accompanying ammonites of age significance, he concluded that their age was Upper Callovian from the range of the genus elsewhere, mainly in Europe. The evidence suggests that the most likely age of the Yemeni occurrence is Coronatum Zone, Middle Callovian, but Upper Callovian is a possibility.

OCCURRENCE. Middle and upper parts of the Shuqra Formation, Jebel Billum and Al Ma'abir; Middle Callovian, Coronatum Zone (?or Upper Callovian).

Family **ASPIDOCERATIDAE** Zittel, 1895
Subfamily **ASPIDOCERATINAE** Zittel, 1895

REMARKS. Aspidoceratids make up only a small proportion of the Yemen ammonite fauna in numbers of specimens, but they are present at five horizons from the top of the Oxfordian to the top of the Tithonian. The view sometimes expressed (eg. Callomon & Cope, 1971: 159; Callomon, *in* Verma & Westermann, 1984: 64) that high variation in whorl shape and ornament will be found in single-bed assemblages of Aspidoceratids does not seem to be borne out in the single horizon collections from Yemen. Thus the collections of *Orthaspidoceras gortanii*, *O. avellanum* and *Simaspidoceras argobbae* described below are as closely defined as many other species of ammonites from single horizons. Much progress in sorting out the synonymy of the multiplicity of specific names was made by Checa (1985) in his monograph on the family, and his work is largely followed here. However, comment on parts of the generic nomenclature seems to be necessary. *Aspidoceras* itself is bituberculate, at least at some growth stage, and its whorls are typically involute, globular and depressed, though more evolute species do occur, eg. *A. apenninicum*. *Orthaspidoceras* embraces species with only one row of tubercles or spines, which may occur anywhere between mid-lateral and the edge of the umbilicus. In the latter position they sometimes point inwards over the umbilicus, but some specimens have been figured (Checa, 1985: pl. 29, fig. 1; pl. 32, fig. 3; pl. 33, fig. 1) that have tubercles pointing inwards over the umbilicus on the inner whorls, changing to tubercles directed normal to the surface on larger whorls. Such specimens seem to cast doubt on the usefulness of the genus *Physodoceras* Hyatt, 1900, which has been used for specimens that have inwardly pointing tubercles on inner whorls. According to Checa (1985: 132) *Physodoceras* only occurs as high as the Divisum Zone, or possibly the Acanthicum Zone, in the Kimmeridgian. There are higher species, mainly from the Beckeri Zone onwards, that tend towards more involute whorls and loss of ornament, and Checa (1985: 184) divided these off as his new genus *Schaireria* (type species, *Aspidoceras avellanum* Zittel, 1870). These appear to be a continuation of trends already seen in *Orthaspidoceras*, and it does not seem necessary to split them off as a new genus. In any case, most of the poorly dated ammonites from Ethiopia described by Scott (1943) are almost certainly of Beckeri/Hybonotum Zone age, rather than older, and one of them is *Glabrophysodoceras* Scott (1943: 82), which is involute and nearly smooth, and has priority over *Schaireria* if a new generic name is thought to be necessary for such forms. The youngest recorded Aspidoceratids are *Aspidoceras rogoznicense* (Zejszner), *A. taverai* Checa and *Orthaspidoceras [?Schaireria] longaeva* (Leanza) in the lower two zones of the Berriasian in SE Spain (Checa *et al*, 1986).

Genus ***ASPIDOCERAS*** Zittel, 1868

TYPE SPECIES. *Ammonites rogoznicensis* Zejszner, 1846, by monotypy.

SYNONYM. *Acanthosphaerites* Rollier, 1922 (type species, *Ammonites acanthicus* Oppel, 1863).

Aspidoceras rogoznicense (Zejszner, 1846) Pl. 10, fig. 1

1846 *Ammonites rogoznicensis* Zejszner: pl. 4, fig. 4.
1868 *Ammonites (Aspidoceras) rogoznicense* Zejszner; Zittel: 116, pl. 24, figs 4, 5.
1870 *Aspidoceras zeuschneri* Zittel: 87, pl. 7, fig. 4.
?1897 *Aspidoceras euomphalum* Steuer: 69, pl. 5 (19), figs 1–4.
1928 *Aspidoceras haupti* Krantz: 12, pl. 4, fig. 2.
?1943 *Aspidoceras iphiceroides* Waagen; Scott: 79, pl. 16, figs 1, 3.
1973 *Aspidoceras* cf. *andinum* Steuer; Verma & Westermann: 191, pl. 36, fig. 1.
1973 *Aspidoceras haupti* Krantz; Verma & Westermann: 193, pl. 36, fig. 2; pl. 37, fig. 1.
1973 *Aspidoceras* cf. *haupti* Krantz; Verma & Westermann: 194, pl. 35, fig. 3.
1980 *Aspidoceras euomphalum* Steuer; Leanza: 41, pl. 8, fig. 1.
1985 *Aspidoceras rogoznicense* (Zejszner); Checa: 98, pl. 16, figs 1–4.

MATERIAL. Two specimens, CA579–80, from bed 36, Mintaq Member, Mintaq Salt Dome.

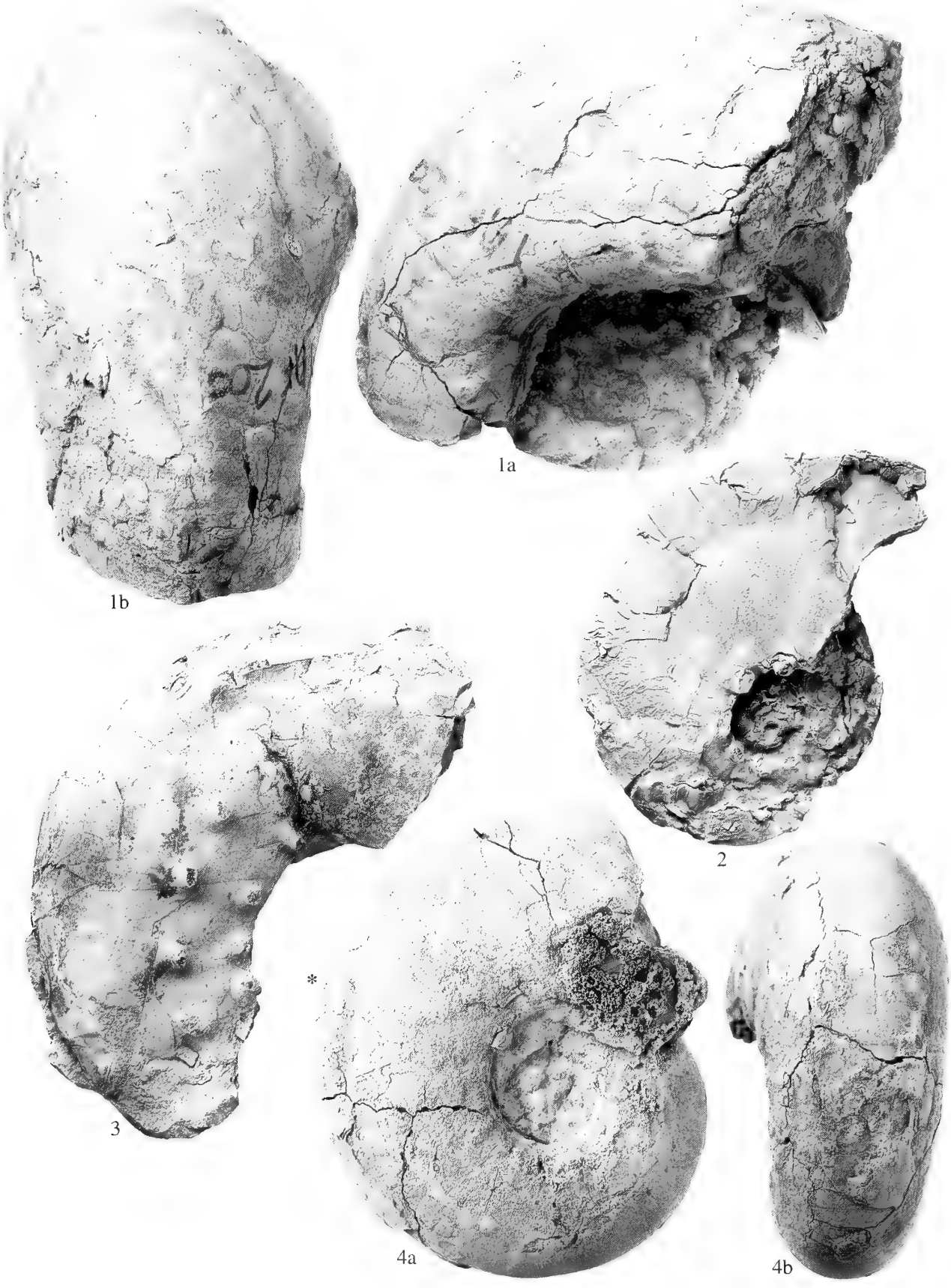
MEASUREMENTS

	D	Wh	Wb	U
CA579	205	86 (0.42)	120 (0.59)	—
CA580	102	42 (0.41)	56 (0.55)	—

DESCRIPTION. The larger specimen consists of a third of a whorl of massive body-chamber, which is uncrushed near the aperture at 205 mm diameter, but is progressively crushed on one side towards the smaller broken end; poorly preserved parts of the inner whorls are also seen; there are no septa on the body-chamber, which may be complete at the aperture and is possibly adult. The final whorl is very massive and has an evenly rounded, depressed whorl section, a deep umbilicus and vertical umbilical walls. Traces of two rows of bold tubercles can be seen on the inner whorls, and reduced tubercles remain on the outer whorl, which appears to show modified adult ornament. Part of the latter is low relief ribbing or striation present near the aperture, where it is projected forwards in crossing the venter, and includes one deeper groove that might be a constriction.

The smaller specimen is seen mainly as a series of whorl cross-sections of up to 100 mm diameter preserved in very hard limestone matrix; as in the larger specimen, the whorl thickness is considerably more than the whorl height.

REMARKS. According to the work of Checa (1985: 111 &c) a bituberculate *Aspidoceras* with massive depressed whorls in the Berriasian has to belong to *Aspidoceras rogoznicense* (Zejszner). In



1b

1a

2

3

*

4a

4b

its type area at Rogoznik, southern Poland, that species ranges from the top of the Hybonotum up to the Fallauxi Zones in the Lower Tithonian according to the records of Kutek & Wierbowski (1986: 292, table 2). Its presence lower in the Hybonotum Zone alongside *A. longispinum* seems to be problematical, because the two species are very close in morphology, and it seems more likely that *A. rogoznicense* is the phylogenetic successor of *A. longispinum* in which the whorls have become more depressed and the two rows of tubercles are slightly closer together. However, there is no doubt that *A. rogoznicense* ranges up to the top of the Tithonian and into the basal zone of the Berriasian (Checa *et al*, 1986: 163), and the Upper Tithonian examples from the Internispinosum Zone (=low Upper Tithonian – see Howarth, 1992: 600, fig. 2) of Argentina (Krantz, 1928; Leanza, 1980) and top Lower Tithonian and Upper Tithonian of Mexico (Verma & Westermann, 1973) bear this out. In fact the two specimens figured by Krantz and Leanza are especially fine examples of *A. rogoznicense*, both showing the striae and low ribs or folds on the surface of the shell that can also be seen on the Yemen example.

OCCURRENCE. Mintaq Member, Mintaq Salt Dome; Occitanica Zone, Berriasian.

Aspidoceras cf. *taverai* Checa, 1985 Pl. 10, fig. 3

cf. 1985 *Aspidoceras taverai* Checa: 109, pl. 19, figs 1–4; pl. 20, fig. 1.

MATERIAL. Four specimens: CA581 from bed 30, CA582 from bed 57 and CA583–54 from bed 60, Mintaq Member, Mintaq Salt Dome.

DESCRIPTION. CA581 is an internal mould of half a whorl of laterally crushed body-chamber, with parts of a large pair of laevaptychi in place in the broken aperture at the larger end at a diameter of 155 mm; there is no trace of the last septum of the phragmocone at the smaller end; the crushing is such that the original shape of the whorl cross-section cannot be seen, but at a diameter of approximately 140 mm the distance between corresponding lateral tubercles on opposite sides of the whorl *measured on the surface of the venter* is 63 mm, and at this position the distance between the umbilical and lateral tubercle rows is 19 mm. CA582 is half a whorl of poorly preserved, but largely uncrushed phragmocone 75 mm diameter, with a roughly circular whorl section. CA583–84 are fragments of septate whorls 80–90 mm diameter. The whorl section is rounded and only slightly depressed in all of them; the ornament consists of umbilical and lateral tubercles of medium size, and there are 8–9 tubercles per half whorl in both rows; there are no ribs, but traces of striae are visible on CA583.

REMARKS. It is clear from the work of Checa (1985) that these Berriasian bituberculate ammonites belong to either *Aspidoceras rogoznicense* (Zejszner) or his new species *A. taverai*. From the rough measurements given above, it can be estimated that at 140 mm diameter the whorl thickness is about 55–58 mm (definitely less than 63 mm), and at a whorl height of approximately 55 mm the distance between the rows of tubercles is 19 mm. Such a whorl thickness is too low for *A. rogoznicense* according to Checa's (1985: 223–24, 363–64) measurements and graphs, but could belong to the somewhat less depressed *A. taverai*, and the distance between the rows of tubercles is slightly too high for *A. rogoznicense*. For these reasons it is more probable that these Mintaq ammonites are *A. taverai* rather than *A. rogoznicense*. Checa (1985: 112, explanation of pl. 19, fig. 2) and Checa *et al* (1986: 164) recorded *A. taverai* from the Upper Tithonian, Durangites Zone, and from the Lower Berriasian, Jacobi Zone, in SE Spain.

OCCURRENCE. Mintaq Member, Mintaq Salt Dome; Occitanica Zone, Berriasian.

Aspidoceras longispinum (J. de C. Sowerby, 1825) Pl. 9, fig. 2; Pl. 11, fig. 5

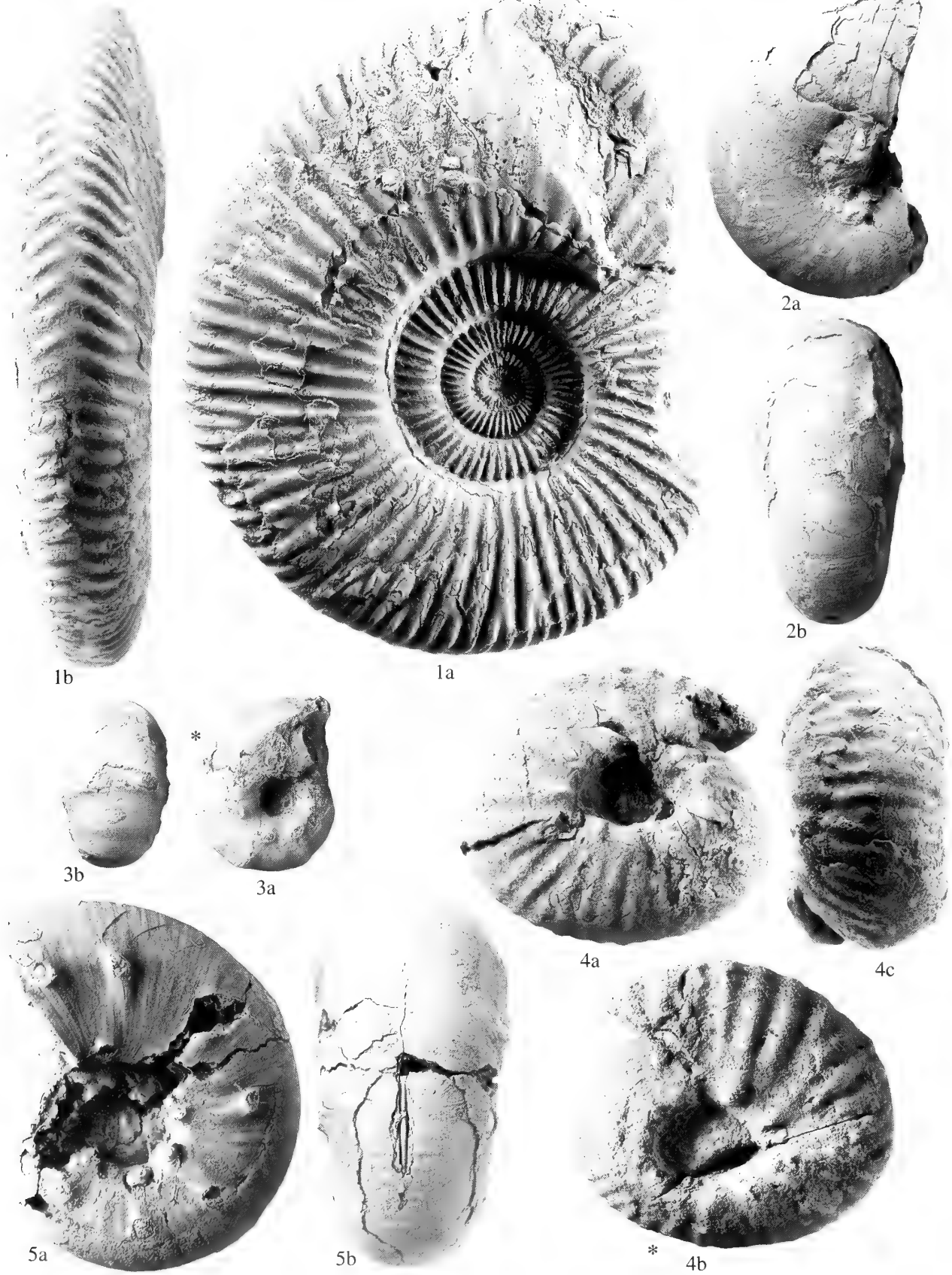
1825 *Ammonites longispinus* J. de C. Sowerby: 164, pl. 51, fig. 2.
1875 *Aspidoceras iphiceroides* Waagen: 102, pl. 23, figs 1, 2.
1875 *Aspidoceras wynnei* Waagen: 103, pl. 21, fig. 5, pl. 22.
1875 *Aspidoceras binodiferum* Waagen: 105, pl. 24.
1880 *Ammonites longispinus* J. de C. Sowerby; Damon: pl. 14, fig. 2.
1888 *Ammonites bispinosus* Zieten; Quenstedt: 1031, pl. 118, figs 1–5.
1905 *Aspidoceras somalicum* Dacqué: 149, pl. 17, fig. 1.
1910 *Aspidoceras iphiceroides* Waagen; Dacqué: 24, pl. 1, fig. 8; pl. 4, fig. 4.
1910 *Aspidoceras kilindianum* Dacqué: 25, pl. 1, fig. 9; pl. 3, fig. 6.
1930 *Acanthosphaerites* aff. *longispinum* (J. de C. Sowerby); Spath: 58, pl. 7, fig. 6.
1930 *Acanthosphaerites* aff. *iphiceroides* (Waagen); Spath: 60, pl. 7, figs 1, 8.
1931 *Aspidoceras* aff. *acanthicum* (Oppel); Spath: 624, pl. 123, fig. 7.
1931 *Aspidoceras caroli* Spath: 632, pl. 118, figs 2, 7.
1931 *Aspidoceras lerense* Spath: 633, pl. 122, fig. 1.
1931 *Aspidoceras* aff. *hoplisum* (Oppel); Spath: 634, pl. 118, fig. 1.
1931 *Aspidoceras iphiceroides* (Waagen); Spath: 635, pl. 123, fig. 8.
1931 *Aspidoceras mombasense* Spath: 636 (*nom. nov.* for Spath, 1930: pl. 7, fig. 8).
1931 *Aspidoceras wynnei* Waagen; Spath: 638, pl. 124, fig. 7.
1931 *Aspidoceras subwynnei* Spath: 640, pl. 74, fig. 2; pl. 117, fig. 5; pl. 122, fig. 5.
1959 *Aspidoceras bispinosum* (Zieten); Venzo: 164, pl. 12, fig. 4; pl. 14, figs 3, 4.
1959 *Aspidoceras longispinum* var. *antsalovensis* Collignon: pl. 110, figs 404, 405.
1959 *Aspidoceras acanthicum* (Oppel); Collignon: pl. 128, figs 479, 480.
1959 *Aspidoceras* cf. *subwynnei* (Spath); Collignon: pl. 129, fig. 484.
1959 *Aspidoceras bertucati* Collignon: pl. 130, fig. 486.
1959 *Aspidoceras iphicerum* (Oppel); Collignon: pl. 131, fig. 490.

PLATE 10

Fig. 1 *Aspidoceras rogoznicense* (Zejszner), bed 36, Mintaq Member (fauna 13), Mintaq Salt Dome. **1a, 1b,** CA579, body-chamber, ×0.59.

Figs 2, 4 *Orthaspidoceras avellanum* Zittel. **2,** lower marly part of Kilya Member, Wadi Kilya (fauna 7), CA1206. **4a, 4b,** upper marly part of Kilya Member (fauna 8), Wadi Kilya, CA1204, ×0.67.

Fig. 3 *Aspidoceras* cf. *taverai* Checa, body-chamber, with part of a large aptychus (*Laevaptychus*, with hinge-line uppermost) in the aperture; bed 30, Mintaq Member (fauna 13), Mintaq Salt Dome, CA581, ×0.76.


1b
1a
2a
2b
3b
3a
4a
4c
5a
5b
4b

1971 *Aspidoceras longispinum* (J. de C. Sowerby); Callomon & Cope: 174, pl. 12, figs 1–3.
1979 *Aspidoceras longispinum* (J. de C. Sowerby); Schairer & Barthel: 18, pl. 3, figs 3–8; pl. 4.
1984 *Aspidoceras* aff. *acanthicum* (Oppel); Verma & Westermann: 65, pl. 15, fig. 1.
1984 *Aspidoceras iphiceroides* (Waagen); Verma & Westermann: 66, pl. 15, figs 2, 3; pl. 16, figs 1–3.
1984 *Aspidoceras* cf. *iphicerum* (Oppel); Verma & Westermann: 68, pl. 16, figs 4, 5.
1985 *Aspidoceras longispinum* (J. de C. Sowerby); Checa: 76, pl. 9, figs 1–3; pl. 10, fig. 2; pl. 14, fig. 2; pl. 15, fig. 1.

MATERIAL. 12 specimens from the Kilya Member: CA1184–86 from the upper marly part, CA1187–89 from the middle limestone part and CA1190 from the top of the lower marly part, all in Wadi Kilya; CA1037 and CA1038 from a shell bed at the top of the middle limestone part, and CA1035, CA1036 and SM F.12201 from the base of the same part of the Kilya Member in Naifa Cliff.

DESCRIPTION. The largest specimen is poorly preserved and partly crushed, but is 300 mm diameter at its (?adult) mouth-border, has a little more than half a whorl of body-chamber, and a final septum at about 210 mm diameter; apart from remnants of large umbilical tubercles its ornament is not preserved. Three specimens are poorly preserved fragments of smaller body-chambers. Three others are crushed phragmocones, all strongly tuberculate, one of which ends at 120 mm diameter and is followed by one-third of a whorl of body-chamber. The remaining five specimens are well-preserved phragmocones up to 120 mm diameter.

The whorls are evolute with a rounded depressed whorl section. The ornament consists of two rows of small to medium sized tubercles, one at the umbilical edge, the other at, or just ventral of, the middle of the whorl side. In both rows the number of tubercles varies from 9–18 per whorl at 75 mm diameter. Ribs are mostly absent, but low undulations occur between the rows of tubercles and there are striae on the shell surface.

MEASUREMENTS

	D	Wh	Wb	U
CA1185	108.0	41.2 (0.38)	56.5 (0.52)	—
CA1186	75.0	32.5 (0.43)	37.3 (0.50)	21.2 (0.28)
SM F.12201	54.3	22.0 (0.41)	26.8 (0.49)	18.9 (0.35)

REMARKS. A bituberculate species of *Aspidoceras* is widely distributed in Kenya, Somalia, Ethiopia, Yemen and Cutch. In Kenya, Yemen and Cutch it undoubtedly occurs in the Beckeri and Hybonotum Zones. Some of the Yemen specimens (eg. Pl. 9, fig. 2) are morphologically identical with the holotype of *A. longispinum* and with Damon's specimen, both refigured by Callomon & Cope (1971), and of Eudoxus Zone age in southern England. The 12 Yemen and about 35 other figured specimens from east Africa and Cutch of this consistently bituberculate, massive-whorled, depressed species show a moderate amount of variation in whorl proportions and development of tubercles. Much of the variation in tubercle size and development is due to the differing preservation, because tubercles are always prominent where the shell is preserved, but they are much reduced or almost absent on inner moulds, especially when such moulds are abraded.

A. rogoznicense is a very similar, but slightly younger species, which differs in having more depressed whorls, and the two rows of tubercles are slightly closer together (compared with the whorl height) according to the analysis of Checa (1985: 98).

OCCURRENCE. Lower, middle and upper parts of the Kilya Member, Naifa Formation, Naifa Cliff and Wadi Kilya; Beckeri Zone, Upper Kimmeridgian, and Hybonotum Zone, Lower Tithonian.

Aspidoceras apenninicum Zittel, 1870

Pl. 9, fig. 3; pl. 12, fig. 4

1869 *Aspidoceras apenninicum* Zittel: 149.
1870 *Aspidoceras apenninicum* Zittel; Zittel: 78, pl. 5 (29), fig. 6.
1901 *Aspidoceras apenninicum* Zittel; Canavari: 12 (84), pl. 3 (22), figs 1, 2.
1943 *Aspidoceras evolutum* Scott: 78, pl. 17, figs 1, 4.
1959 *Epaspidoceras rupellense* (d'Orbigny); Collignon: pl. 132, fig. 493.
1984 *Aspidoceras* cf. *apenninicum* Zittel; Verma & Westermann: 69, pl. 17, fig. 1.
1985 *Aspidoceras apenninicum* Zittel; Checa: 84, pl. 13, figs 1–3; pl. 14, fig. 1.

MATERIAL. Nine specimens, CA1191–99, from the upper part of the middle limestone part of the Kilya Member in Wadi Kilya.

DESCRIPTION. The collection consists of nine solid, uncrushed, roughly preserved body-chambers, the largest being part of a specimen of about 230 mm diameter. Final septa are preserved at the smaller end of seven specimens, at diameters in the range 103–180 mm, and poorly preserved crushed inner whorls are present in two specimens. The largest specimen has whorl height and breadth of 68.5 and 63 mm respectively at 230 mm diameter. The whorls are evolute and the whorl section is quadrate and only slightly higher than broad. The umbilical walls are rounded and merge smoothly into the whorl sides, which converge slowly towards the arched venter. At the largest sizes the venter becomes slightly angled. The ornament consists of prominent umbilical and ventro-lateral tubercles, and the latter tend to become clavate at large sizes. Rounded ribs of low relief connect the tubercles and are mostly single, but occasionally two ribs issue from an umbilical tubercle, so that there are a few more ventro-lateral than umbilical tubercles. Ribs remain of low relief and are angled forwards on the venter, but they tend to become raised in mid-venter, which becomes increasingly angled with growth.

MEASUREMENTS

	D	Wh	Wb	U
CA11922	153	48.5 (0.32)	46.5 (0.30)	66.5 (0.43)
CA11965	230	68.5 (0.30)	63.0 (0.27)	—
CA11998	188	62.0 (0.33)	57.0 (0.30)	—

PLATE 11

Fig. 1 *Idoceras ahwarense* sp. nov, **holotype**, Ghanam al Kuffar (13°45'N, 46°41'E), in Wadi Ahwar, 30 km north of Ahwar and 36 km north of the mouth of Wadi Ahwar on the coast of the Gulf of Aden. **1a, 1b,** C.71097, wholly septate.

Fig. 2 *Orthaspidoceras avellanum* Zittel, upper marly part of Kilya Member (fauna 8), Wadi Kilya. **2a, 2b,** CA1205.

Fig. 3 *Simaspidoceras argobbae* (Dacqué), Breadloaf Concretions, Kilya Member (fauna 7), east cliff, Wadi Arus. **3a, 3b,** CA741.

Fig. 4 *Erymnoceras (Pachyermnoceras) jarryi* (Douvillé), 17 m below top of the Upper Shuqra, Shuqra Formation (fauna 1), central Jebel Billum. **4a-4c,** CA838.

Fig. 5 *Aspidoceras longispinum* (J. de C. Sowerby), upper marly part of Kilya Member (fauna 8), Wadi Kilya. **5a, 5b,** CA1186, wholly septate.

REMARKS. *Aspidoceras apenninicum* is one of the most evolute species of *Aspidoceras*. Its evolute, massive whorls, with rudimentary ribbing, two rows of large tubercles and raised mid-venter are distinctively different from the more involute, globose and smoother whorls of most other species. The outer whorls of *Pseudowaagenia acanthomphala* (Zittel, 1869; 1870: 79, pl. 5, fig. 4; Checa, 1985: 127) bear some resemblance, but they are smaller and less massive, and the inner whorls are compressed, more involute and have many more, smaller umbilical tubercles. Inner whorls are not preserved in the present collection, but these large massive body-chambers are unlikely to belong to *Pseudowaagenia*. Zittel's (1870) originals and Canavari's (1901) figured specimens are from the Apennines of central Italy where they occur in the top Kimmeridgian or bottom Tithonian, but are not well-dated in terms of modern zones. Checa (1985: 85, 111) had better evidence from south-east Spain where the species occurs mainly in the Beckeri Zone and less commonly in the upper part of the Eudoxus Zone below. A large well-preserved specimen from Ethiopia, which is possibly still septate at its maximum size of 166 mm diameter, was figured as *Aspidoceras evolutum* by Scott (1943: pl. 17, figs 1, 4); its age was not accurately determined, but could be Beckeri Zone, like many of the other ammonites described by Scott. Together with Collignon's (1959) specimen from a similar horizon in Madagascar and Verma & Westermann's (1984) example from the Beckeri Zone at Mombasa, these are the only previous records of this species in the east African – Indian Ocean area.

OCCURRENCE. Middle part of the Kilya Member, Wadi Kilya; Beckeri Zone, Upper Kimmeridgian.

Genus ***ORTHASPIDOCERAS*** Spath, 1925

TYPE SPECIES. *Ammonites orthocera* d'Orbigny, 1850.

SYNONYMS. *Glabrophysodoceras* Scott, 1943: 82 (type species, *G. abyssinianum* Scott, 1943); *Shaireria* Checa, 1985: 184 (type species, *Aspidoceras avellanum* Zittel, 1870).

Orthaspidoceras gortanii (Venzo, 1959) Pl. 12, figs 1, 2

1959 *Aspidoceras liparum* (Oppel); Venzo: 160, pl. 9, figs ?4, 5; pl. 13, fig. 2.
1959 *Physodoceras altenense* d'Orbigny; Venzo: 168, pl. 14, fig. 5.
1959 *Physodoceras gortanii* Venzo: 173, pl. 11, fig. 1.
1985 *Orthaspidoceras gortanii* (Venzo); Checa: 171, fig. II.3.42B; pl. 33, fig. 2.

MATERIAL. Five specimens, CA1039–43, 19.7 m above the base of the Kilya Member in Naifa Cliff.

DESCRIPTION. All five specimens are body-chambers; three are complete and adult at 140, 147 and 154 mm diameter, with body-chambers 200°–215° long; one is complete but immature at 130 mm diameter; one has the final quarter whorl missing. The final septum at the end of the crushed phragmocone is present in all five, but no earlier whorls are preserved. The whorls are involute and globose, though the umbilicus widens markedly towards the final mouth-border. The whorl section is elliptical, slightly depressed, with vertical umbilical walls, and evenly rounded whorl sides and venter. Large spiny umbilical tubercles project mainly normal to the shell surface, though a few are directed inwards over the umbilicus. Many tubercles tend to be clavate, and they are widely spaced, at a density of only 2 or 3 on the final half whorl of the body-chamber (ie. 4–6 per whorl at 150 mm diameter). Irregular fold-like ribs of very low relief are present on most specimens, and in one they become more prominent in the ventro-lateral region. Striae of similar shape are present where the shell is preserved.

MEASUREMENTS

	D	Wh	Wb	U
CA1039	138	53.5 (0.39)	56.5 (0.41)	43.0 (0.31)
CA1041	149	51.0 (0.34)	54.0 (0.36)	54.5 (0.37)
CA1040	132	48.5 (0.37)	50.0 (0.38)	42.5 (0.32)
CA1042	126	48.5 (0.38)	50.5 (0.40)	31.5 (0.25)
CA1043	120	53.0 (0.44)	54.5 (0.45)	32.0 (0.27)

REMARKS. The evenly rounded globose whorls, and the single row of tubercles, here placed near the umbilical edge rather than mid-laterally, are characteristic of *Orthaspidoceras*. Although there are several closely similar species to which these Yemen specimens might belong, there is no doubt that they are the same as three specimens from Ethiopia figured by Venzo, one of which (Venzo, 1959: pl. 11, fig. 1) is the holotype of *O. gortanii*; they have widely spaced tubercles, only 4–6 per whorl, on the body-chamber. The Beckeri Zone date of *O. gortanii* in Yemen suggests that this might also be the date of the Ethiopian specimens, though Zeiss (1971: 537, table 1) placed them slightly lower, in the Eudoxus Zone. Other species that are similar to *O. gortanii* are *O. liparum* (Oppel; holotype figured by Checa, 1985: pl. 33, fig. 1), and *O. lallierianum* (d'Orbigny, 1850: 542, pl. 208; type specimens figured by Hantzpergue, *in* Fischer, 1994: 178, pl. 80, figs 1, 2), which have slightly more umbilical tubercles and occur in the Eudoxus Zone.

OCCURRENCE. The lower marly part of the Kilya Member, Naifa Formation, Naifa Cliff; Beckeri Zone, Upper Kimmeridgian.

Orthaspidoceras avellanum (Zittel, 1870) Pl. 10, figs 2, 4; Pl. 11, fig. 2

1870 *Aspidoceras avellanum* Zittel: 86, pl. 7 (31), figs 2, 3.
1872a *Aspidoceras avellanum* Zittel; Gemmellaro: 151, pl. 18, fig. 3 [p. 51, pl. 10, fig. 3 in reprint].
1905 *Aspidoceras altenense* (d'Orbigny); Dacqué: 150, pl. 17, fig. 2.
?1930 *Acanthosphaerites deaki* (Herbich); Spath: 60, pl. 8, figs 3, 5, 6.
?1943 *Physodoceras altenense* (d'Orbigny); Scott: 80, pl. 17, figs 2, 3.
?1943 *Physodoceras gregoryi* (Spath); Scott: 81, pl. 16, figs 2, 4.
1943 *Glabrophysodoceras ganamense* Scott: 83, pl. 19, figs 2, 3.
1960 *Physodoceras avellanum* (Zittel); Collignon: pl. 160, figs 635, 636.
1984 *Aspidoceras (Physodoceras)* cf. *avellanum* Zittel; Verma & Westermann: 70, pl. 17, fig. 2.

PLATE 12

Figs 1, 2 *Orthaspidoceras gortanii* (Venzo), 19.7 m above the base of the Kilya Member (fauna 7), Naifa Cliff. **1a, 1b,** CA1039, ×0.68; **2a, 2b,** CA1040, ×0.68.

Fig. 3 *Simaspidoceras argobbae* (Dacqué), Breadloaf Concretions, Kilya Member (fauna 7), east cliff, Wadi Arus. **3a, 3b,** CA742.

Fig. 4 *Aspidoceras apeninnicum* Zittel, upper part of middle limestone part of Kilya Member (fauna 7), Wadi Kilya. **4a, 4b,** CA1191, ×0.69.

Fig. 5 *Laevaptychus*, lower marly part of Kilya Member (fauna 7), Wadi Kilya. **5a, 5b,** matching pair of aptychi, CA1230, 1231.


1b
1a
*
4b
2b
2a
*
3a
*
4a
*
5a
5b
3b

1984 *Aspidoceras (Physodoceras) circumspinosum* (Oppel); Verma & Westermann: 71, pl. 17, fig. 3.
1985 *Schaireria avellana* (Zittel); Checa: 197, pl. 40, figs 1, 2; pl. 41, fig. 1.

MATERIAL. 18 specimens: CA1204–05 from the upper marly part, and 16 (including CA1206–19) from the lower marly part of the Kilya Member in Wadi Kilya.

DESCRIPTION. The 16 examples from the lower marly part of the Kilya Member are from a shell bed; all are crushed flat laterally, and they are up to 88 mm diameter. The two from the upper marly part are better preserved and are not crushed; one (pl. 10, fig. 4) is probably septate up to 115 mm diameter, then has a quarter of a whorl of body-chamber up to its aperture at 131 mm diameter; the other is 59 mm diameter, and apparently is an immature, being septate up to 55 mm diameter, then has a short length of body-chamber. The whorl section is nearly circular, being only slightly depressed, and the umbilical edge is rounded except where accentuated by the tubercles. The inner whorls bear large spiny umbilical tubercles directed inwards over the umbilicus, and there are occasional lateral tubercles in some specimens. The density of the umbilical tubercles is 10–12 per whorl at 30–50 mm diameter decreasing to 8–10 at 60–80 mm diameter, while the lateral tubercles are very irregular at only 2–4 per whorl. In the largest ammonite all tubercles disappear by 80 mm diameter and the specimen becomes smooth. There are no ribs.

MEASUREMENTS

	D	Wh	Wb	U
CA1024	126.0	56.0 (0.45)	59.5 (0.47)	36.3 (0.29)
CA1024	107.5	44.2 (0.21)	46.5 (0.43)	25.7 (0.24)
CA1025	58.7	26.3 (0.45)	28.3 (0.48)	15.9 (0.27)

REMARKS. This is a species of *Orthaspidoceras* that occurs in the Beckeri and Hybonotum Zones in several areas of east Africa. Verma & Westermann (1984) described 10 specimens from the Hybonotum Zone of Mombasa, and Scott (1943) had three specimens from Ethiopia that probably belong to this species. The smoothly rounded, moderately involute whorls, in which whorl height and thickness are almost equal, and the reduction or disappearance of the umbilical tubercles at larger sizes are distinctive. Of the similar Aspidoceratids in the same horizons in Yemen, *O. gortanii* is more evolute and has large umbilical tubercles on the body-chamber, *Aspidoceras longispinum* is bituberculate throughout growth and has more massive, more depressed whorls, and *A. apenninicum* is much more evolute.

OCCURRENCE. Upper and lower marly parts of the Kilya Member, Naifa Formation, Wadi Kilya; Beckeri Zone, Upper Kimmeridgian, and Hybonotum Zone, Lower Tithonian.

Aspidoceras or *Orthaspidoceras* spp. indet.

MATERIAL. Nine specimens: CA840–42 from the shell bed 26 m above the base of the Arus Member in eastern Jebel Billum; one large specimen (CA1200) from the upper part of the middle limestone part, and three small specimens (CA1201–03) from the base of the same part of the Kilya Member, in Wadi Kilya; one large fragment (CA1044) from the base of the middle limestone part of the Kilya Member in Naifa Cliff; and one very large (300–350 mm diameter) ammonite was photographed 16 m below the top of the Mintaq Member, in the road gorge leading eastwards out of the southern end of Wadi Arus. All are *Aspidoceras* or *Orthaspidoceras*, but are too fragmentary to be identified.

Genus ***SIMASPIDOCERAS*** Spath, 1925

TYPE SPECIES. *Aspidoceras argobbae* Dacqué, 1905.

REMARKS. *Simaspidoceras* is a genus of Aspidoceratinae that has massive whorls and radial ribs, and is characteristic of the Ethiopia – Somalia – south Yemen area. Early records by Dacqué (1905) and Scott (1943) were poorly dated, and Venzo (1959) did not have good evidence of dating. Zeiss (1971: 537, 540) placed the genus in the Lower Kimmeridgian in Ethiopia, but the associated ammonites are not strongly indicative of such a low horizon. Other ammonites accompanying the present specimens provide good evidence that the age of *Simaspidoceras* in southern Yemen is Beckeri Zone, Upper Kimmeridgian and Hybonotum Zone, Lower Tithonian.

Simaspidoceras argobbae (Dacqué, 1905)
Pl. 11, fig. 3; Pl. 12, fig. 3; Pl. 13, fig. 1; Pl. 14, fig. 1; Pl. 15, fig. 6

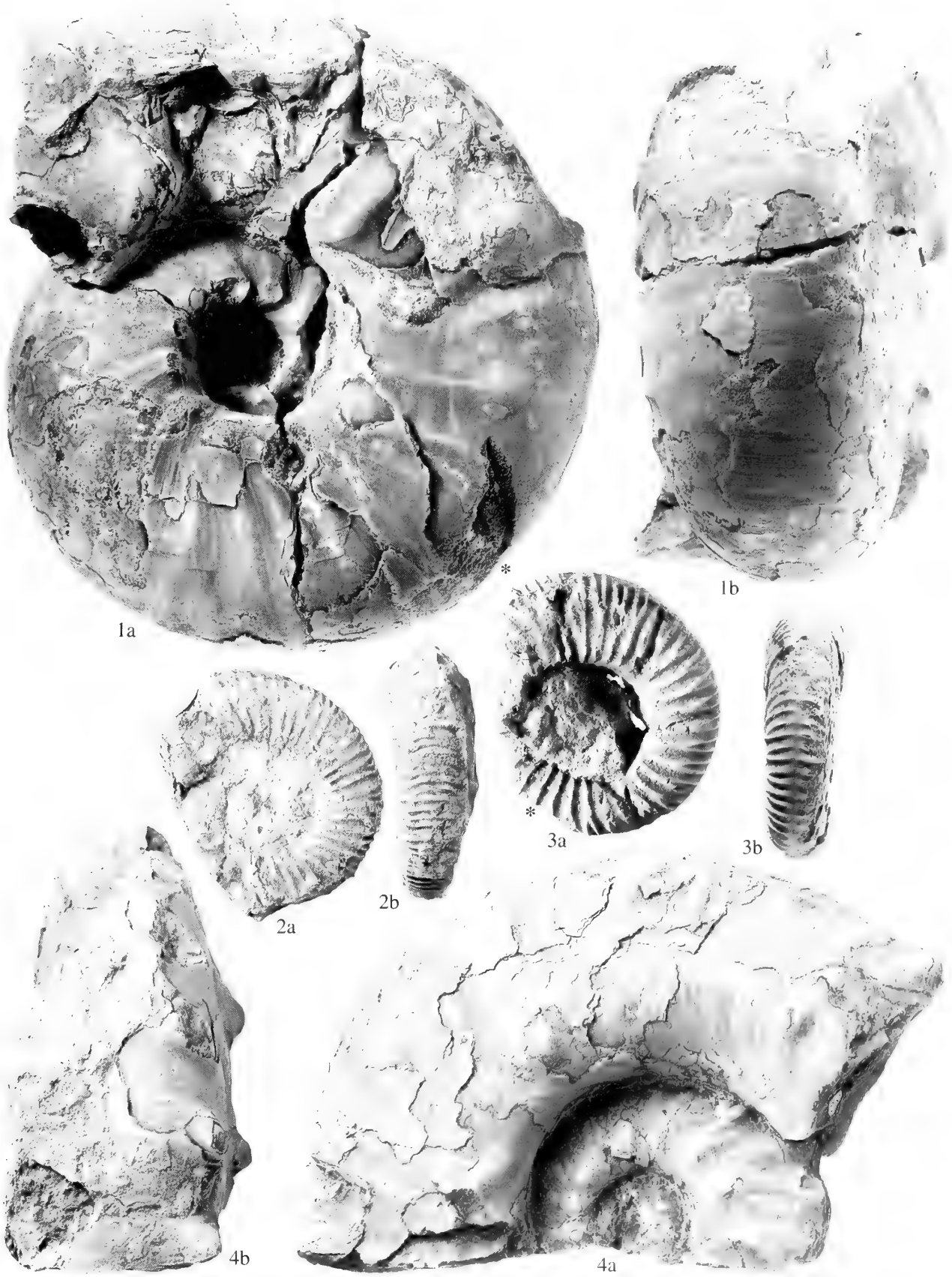
1905 *Aspidoceras argobbae* Dacqué: 151, pl. 18 (5), fig. 1.
1943 *Simaspidoceras ganamense* Scott: 86, fig. 22; pl. 20, figs 1, 2, 5.
1959 *Simaspidoceras argobbae* (Dacqué); Venzo: 175, pl. 11, fig. 4; pl. 12, figs 1a, 1b; pl. 13, figs 1a–1c.
1985 *Simaspidoceras argobbae* (Dacqué); Checa: 177.

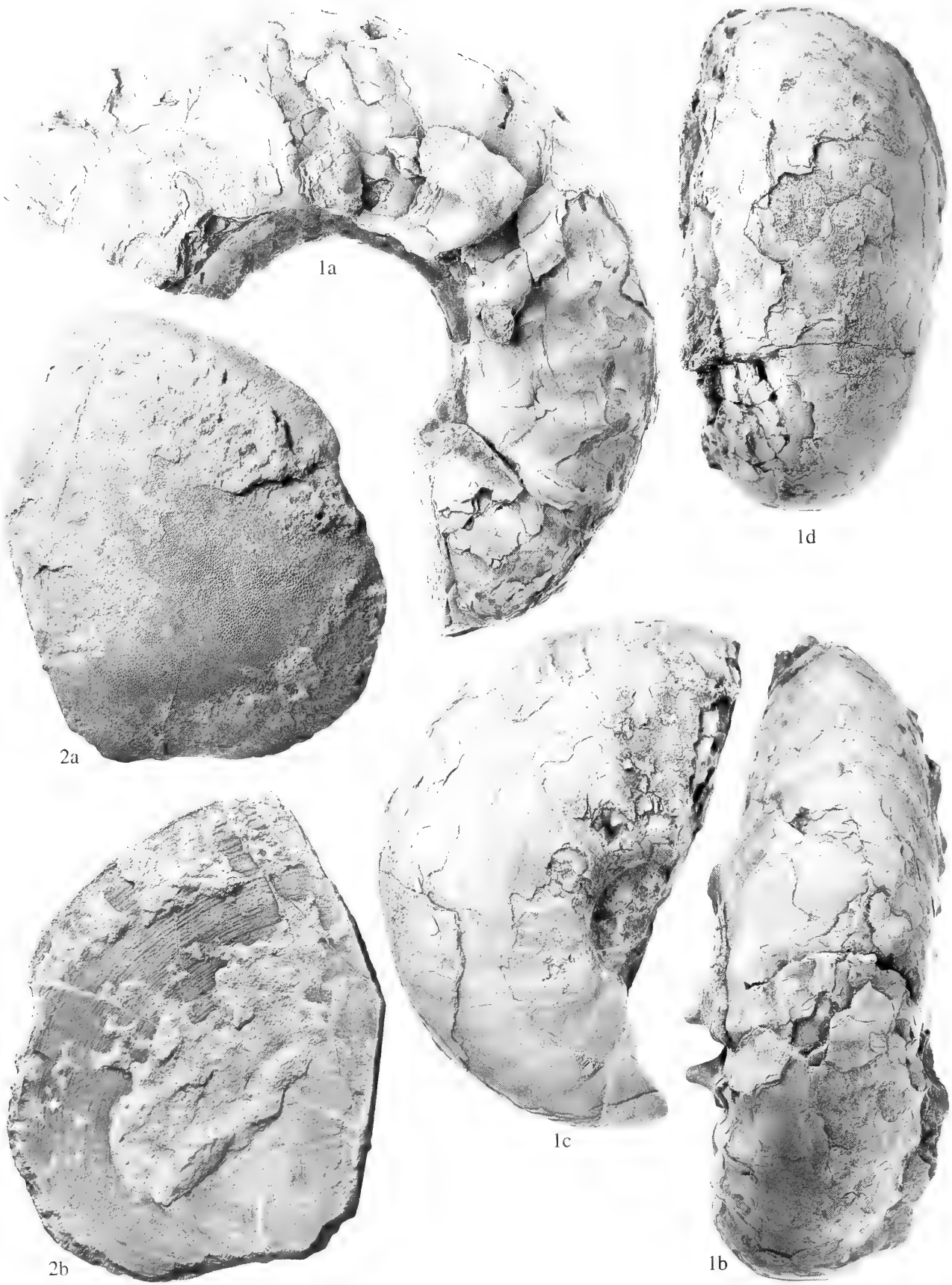
MATERIAL. 14 specimens: eight, CA737–44, from the Breadloaf Concretions in the lower marly part of the Kilya Member in the east cliff of Wadi Arus; SM F.12209 from the base of the middle limestone part of the Kilya Member, and four, CA1045–48, from the lower marly part of that member, all in Naifa Cliff; and CA1220 from the upper marly part of the Kilya Member in Wadi Kilya.

DESCRIPTION. Three of the specimens from Wadi Arus have incomplete body-chambers of 200–220 mm diameter, and the best preserved of them (Pl. 13, fig. 1) has a complete phragmocone ending half a whorl before the aperture; the other five consist of an incomplete fragment 70 mm diameter, and four well-preserved immatures, all with short portions of body-chambers ending at 20–32 mm diameter. SM F.12209 from Naifa Cliff is septate up to 190 mm diameter, then has a quarter of a whorl of body-chamber up to its aperture at 215 mm diameter. The four specimens from the slightly lower horizon in Naifa Cliff (see Howarth & Morris, 1998: fig. 3) are larger, but partly crushed. They have apertures in the range 270–300 mm diameter, one of which appears to contract and might be the adult aperture (Pl. 15, fig. 6). The best preserved of them has two-thirds of a whorl of body-chamber, and has an especially well-preserved inner whorl, now separated (Pl. 14, figs 1c, 1d). The specimen from Wadi Kilya is a poorly preserved fragment of a body-chamber of about 180 mm diameter.

PLATE 13

Fig. 1 *Simaspidoceras argobbae* (Dacqué), Breadloaf Concretions, Kilya Member (fauna 7), east cliff, Wadi Arus. **1a, 1b,** CA737, ×0.65.
Fig. 2 *Aulacosphinctes natricoides* (Uhlig), microbialite boulders, Arus Member (fauna 9), west cliff, Wadi Arus. **2a, 2b,** CA769.
Fig. 3 *Aulacosphinctes spitiensis* (Uhlig), microbialite boulders, Arus Member (fauna 9), east cliff, Wadi Arus. **3a, 3a,** CA768.
Fig. 4 *Simaspidoceras irregulare* (Dacqué), 16.5 m above base of lower marly part of Kilya Member (fauna 7), Naifa Cliff. **4a, 4b,** CA1049, the outer whorl is body-chamber, ×0.57.


1a
*
1b
2a
2b
3a
*
3b
4b
4a


1a
1d
2a
1c
2b
1b

In all specimens the whorls are involute, rapidly expanding, globose and massive up to 200 mm diameter, and become more evolute on the final body-chamber. The whorl section is evenly rounded, without a ventro-lateral angle. Large spinose umbilical tubercles give rise to broad ribs, either singly or in pairs, that are prorsiradiate and fade slightly on the side of the whorl, then swell in the ventro-lateral position to fade again on the venter. A few intercalated ribs commence in the middle of the whorl side. Ventro-lateral tubercles are largely absent, being limited merely to the swellings in the size of the ribs at that position. The four immature specimens (?or microconchs, with last visible suture-lines at the positions indicated by asterisks on Pl. 11, fig. 3 and Pl. 12, fig. 3) from Wadi Arus have depressed cadicone whorls with funnel-shaped umbilici and broad rounded venters; they have only 6 umbilical tubercles per whorl at 23–30 mm diameter; two radial ribs issue from each tubercle, a larger one that has ventro-lateral swellings and passes over the venter as a rounded rib of considerable size, and a smaller one that is much weaker on the venter; the boldness of the larger ribs on the venter gives the whorl growth a segmental appearance, ie. expanding in six segments per whorl. On well-preserved parts of the shell fine growth lines can be seen following the line of the ribs on both inner and outer whorls.

MEASUREMENTS

	D	Wh	Wb	U
CA1046	260	92.0 (0.35)	—	86.0 (0.33)
CA1046	127	61.5 (0.48)	77.0 (0.61)	27.5 (0.22)
SM F.12209	208	86.0 (0.41)	98.0 (0.47)	58.0 (0.28)
CA737	160.5	73.0 (0.45)	85.0 (0.53)	37.3 (0.23)
CA741	27.5	13.2 (0.48)	19.0 (0.69)	5.9 (0.21)
CA742	22.0	9.1 (0.41)	15.3 (0.70)	4.3 (0.20)

REMARKS. *S. argobbae* has massive globose whorls and a small umbilicus that only widens on the adult body-chamber. The whorl section is evenly rounded and ventro-lateral tubercles are absent or very small. These features are clear in the well-preserved example of Pl. 13, fig. 1, and in the larger example of Pl. 14, fig. 1, where the presence of the shell reveals that the umbilical tubercles are spines of considerable length. Small whorls of *S. argobbae* have not been described before, and the curious segmental growth seen on those from Wadi Arus (Pl. 11, fig. 3; Pl. 12, fig. 3) is due to the boldness of the fold-like ribs crossing the venter at these small sizes. By 60 mm diameter the ribs (and their ventro-lateral swellings) have diminished and the line of the venter reverted to a more normal smooth spiral. *S. irregulare* differs in being more evolute in the phragmocone, having a quadrate whorl section with a flatter venter, and large ventro-lateral tubercles. A third species, *S. bucki* Checa (1985: 175, pls 36, 37) is close to *S. argobbae*, but has slightly less massive whorls and more ribs. It occurs in the Divisum Zone at the top of the Lower Kimmeridgian in south-east Spain, this being the only record of *Simaspidoceras* outside Ethiopia, Somalia and Yemen.

OCCURRENCE. Lower, middle and upper parts of the Kilya Member, Naifa Formation, Wadi Arus, Naifa Cliff and Wadi Kilya; Beckeri Zone, Upper Kimmeridgian, and Hybonotum Zone, Lower Tithonian.

Simaspidoceras irregulare (Dacqué, 1905) Pl. 13, fig. 4

1905 *Aspidoceras irregulare* Dacqué: 152 (not figured).
1930 *Aspidoceras irregulare* Dacqué; Basse: 133, pl. 4 (20), fig. 16.
1943 *Simaspidoceras argobbae* (Dacqué); Scott: 84, fig. 20; pl. 21, fig. 2; pl. 23, fig. 1.
1943 *Simaspidoceras harrarense* Scott: 85, fig. 21; pl. 21, fig. 3; pl. 23, fig. 3.
1959 *Simaspidoceras irregulare* (Dacqué); Venzo: 176, pl. 12, fig. 2.
1985 *Simaspidoceras irregulare* (Dacqué); Checa: 182, figs II.3.46B, II.3.47C.

MATERIAL. Three specimens from the Kilya Member: CA1049, from the lower marly part in Naifa Cliff; CA1222 from the base of the middle limestone part, and CA1221 from the upper marly part, in Wadi Kilya.

DESCRIPTION. The specimens from Wadi Kilya are large and roughly preserved; one is probably incomplete at its aperture at 260 mm diameter; traces of a suture-line are visible half a whorl earlier at 190 mm diameter, and this is probably the end of the phragmocone; its inner whorls are covered in hard limestone matrix and are only visible back to about 1½ whorls before the aperture; the other is a short fragment of a very large body-chamber, with a whorl height of 103 mm, and very large umbilical and ventro-lateral tubercles. The specimen from Naifa Cliff is better preserved in dark grey limestone matrix, though one side is crushed and partly absent and the earlier part of the outer whorl is missing; septa are not visible on the outer half whorl which is probably an incomplete body-chamber 230 mm diameter at the aperture; inner whorls are exposed back to about two whorls before the aperture.

The whorls are evolute and massive; the whorl section is quadrate, with nearly flat whorl sides that converge towards a broad flat venter. The most prominent features of the ornament are large umbilical tubercles and large bullate ventro-lateral tubercles; broad undulating ribs between the two rows of tubercles become of very low relief in the middle of the whorl side. A few ribs issue in pairs from the umbilical tubercles, so that there are more ventro-lateral than umbilical tubercles. The ribs are further reduced on the outer whorls, and the umbilical tubercles become more widely spaced. Measurements of CA1049: at 170 mm: 73.5 (0.43), 84.0 (0.49), 53.5 (0.31).

REMARKS. *Simaspidoceras irregulare* differs from *S. argobbae* in having more evolute whorls in the phragmocone, a quadrate whorl section with a flat venter, and large ventro-lateral tubercles.

OCCURRENCE. Lower, middle and upper parts of the Kilya Member, Naifa Formation, Naifa Cliff and Wadi Kilya; Beckeri Zone, Upper Kimmeridgian, and Hybonotum Zone, Lower Tithonian.

Laevaptychus Pl. 10, fig. 3; Pl. 12, fig. 5; Pl. 14, fig. 2

MATERIAL. 81 specimens: 11 from the Mintaq Member (CA585–89 from bed 29 and CA590–95 from bed 30 of the Mintaq Member in the Mintaq Salt Dome); 16 from the Arus Member (CA843–58, from the shell bed, 26 m above the base of that member in eastern Jebel Billum); 1 from the upper marly part of the Kilya Member (CA1223 from Wadi Kilya); 8 from the middle limestone part of the

PLATE 14

Fig. 1 *Simaspidoceras argobbae* (Dacqué), 16.5 m above base of lower marly part of Kilya Member (fauna 7), Naifa Cliff. **1a-1d,** CA1046; 1a, 1b, body-chamber, ×0.47; 1c, 1d, wholly septate inner whorls, ×0.75.

Fig. 2 *Laevaptychus*, bed 29, Mintaq Member (fauna 13), Mintaq Salt Dome. **2a, 2b,** CA586.

Kilya Member (CA1050–51, SM F.12173, F.12206, F.12208 and F.13419, from Naifa Cliff, and CA1228–29 from Wadi Kilya); 44 from the lower marly part of the Kilya Member (CA1224–27 and CA1230–59 from Wadi Kilya, SM F.13420–21 from Jebel Billum, CA745–46, SM F.12159, F.13422 and F.13435 from Wadi Arus, and SM F.12174–76 from Husn Ba Qirwan); CA839 from the Lower Storm Bed, Madbi Formation, central Jebel Billum.

REMARKS. These are typical thick-shelled, broad *Laevaptychus*, punctate on the outer convex surface, and with concentric ribs on the inner surface. Many are in the size range 40–60 mm long, a few are 70–90 mm long (Pl. 14, fig. 2), and the largest is a fragment from an aptychus about 120 mm long. There are several associated pairs of aptychi (Pl. 12, fig. 5). As aptychi mainly from Aspidoceratinae, they confirm the widespread occurrence of that subfamily in the Kimmeridgian, Tithonian and Berriasian of Wadi Hajar. The commonest occurrence is in the lower part of the Kilya Member in Wadi Kilya, where *Orthaspidoceras avellanum* (Zittel) is also common. There are also several large, well-preserved, *Laevaptychus* in the middle beds of the Mintaq Member at Mintaq of mid-Berriasian age, where *Aspidoceras* is poorly preserved, though some are large. The single specimen from the Lower Storm Bed of the Madbi Formation in central Jebel Billum is of lower to mid-Oxfordian age, and is of interest in showing the presence of Aspidoceratinae at that horizon, probably *Euaspidoceras*.

Subfamily **HYBONOTICERATINAE** Callomon, 1981
Genus ***HYBONOTICERAS*** Breistroffer, 1947

TYPE SPECIES. *Ammonites hybonotum* Oppel, 1863.

Hybonoticeras ornatum (Spath, 1931) Pl. 15, fig. 1

1930 *Waagenia* sp. nov., Spath: 62, text–figs 4a, 4b.
1931 *Waagenia ornata* Spath: 649, pl. 118, fig. 5; pl. 120, fig. 1 (holotype).
1931 *Waagenia africana* Spath: 650 (*nom. nov.* for Spath, 1930: 62. text–figs 4a, 4b).
?1959 *Hybonoticeras beckeri extraspinatum* Berckhemer & Hölder: 29, 30, figs 14, 15; pl. 4, fig. 17.
1984 *Hybonoticeras* cf. *ornatum* (Spath); Verma & Westermann: 73, pl. 19, figs 3, 4.

MATERIAL. Two specimens, CA1260–61, from the upper marly part of the Kilya Member in Wadi Kilya.

DESCRIPTION. The larger specimen (CA1260) is a fragment one-third of a whorl long; septa can be seen up to 45° before the aperture, and it might possibly be wholly septate up to its aperture, which is at about 100 mm diameter. The second specimen is a much shorter fragment of a slightly larger whorl, with a whorl height of about 35 mm. The robust whorls have a quadrate whorl section, with sloping umbilical walls. Markedly rursiradiate ribs loop between strong umbilical and ventro-lateral tubercles, and there are a few intermediate non-tuberculate ribs; from the ventro-lateral tubercles, single, twinned or intercalated secondary ribs project strongly forwards on the venter and join coarse raised serrations that border a deep mid-ventral groove.

REMARKS. Spath's holotype is from the Hybonotum Zone at Cutch, and the larger holotype of *Waagenia africana* Spath is from Mombasa; both differ from *H. beckeri* (Neumayr) only in their stronger ornament and broader, more robust whorls. The specimens figured by Verma & Westermann (1984) are two very similar fragments from the bottom of the Hybonotum Zone at Mombasa. Several examples of *Hybnoticeras* from Madagascar were figured by Collignon (1959); most are different (many have smooth, rather than serrate, ventral keels) and the one (Collignon, 1959: pl. 106, fig. 392) which was compared with *H. ornatum* by Verma & Westermann (1984: 75) is too badly figured to be interpreted. This is the most coarsely ribbed species of *Hybonoticeras*, and probably comes from the the lower part of the Hybonotum Zone. *H. beckeri* is less strongly ribbed, and several other species of *Hybonoticeras* are much less strongly ribbed, striate or even smooth.

OCCURRENCE. Upper part of the Kilya Member, Naifa Formation, Wadi Kilya; Hybonotum Zone, Lower Tithonian.

Hybonoticeras cf. *hybonotum* (Oppel, 1863) Pl. 15, fig. 4

1863 *Ammonites hybnotus* Oppel: 254, pl. 71, figs 1–3.
1959 *Hybonoticeras hybonotum* (Oppel); Berckhemer & Hölder: 30, fig. 16; pl. 3, fig. 12; pl. 5, figs 18, 19 (see for synonymy).
1984 *Hybonoticeras* cf. *hybonotum* (Oppel); Verma & Westermann: 73, pl. 18, fig. 2.

MATERIAL. CA1262 from the upper marly part of the Kilya Member in Wadi Kilya.

DESCRIPTION. This is a large septate fragment a quarter of a whorl long, with a maximum whorl height and breadth of 45 mm and 36 mm respectively. It is part of a quickly expanding, massive whorl at about 115 mm diameter. The whorl section is quadrate, with flat sides and venter. Large umbilical tubercles and large widely spaced ventro-lateral tubercles are joined by ribs, some of which are looped between them, and there are many intermediate non-tuberculate ribs. Weak or striate secondary ribs are projected strongly forwards on the sides of the venter, and a deep ventral groove is bordered by slightly raised ridges that are only weakly crenulate.

REMARKS. This large fragment is like *Hybonoticeras hybonotum*, but the whorls are broader and expand more quickly, giving a very massive appearance. The near-flat venter with a prominent groove bordered by low poorly crenulate ridges is very similar to the fragment from the Beckeri Zone at Mombasa figured by Verma & Westermann (1984: pl. 18, fig. 2), and they recorded other fragments from the Hybonotum Zone (Verma & Westermann, 1984: 16, table 2).

OCCURRENCE. Upper part of the Kilya Member, Naifa Formation, Wadi Kilya; Hybonotum Zone, Lower Tithonian.

PLATE 15

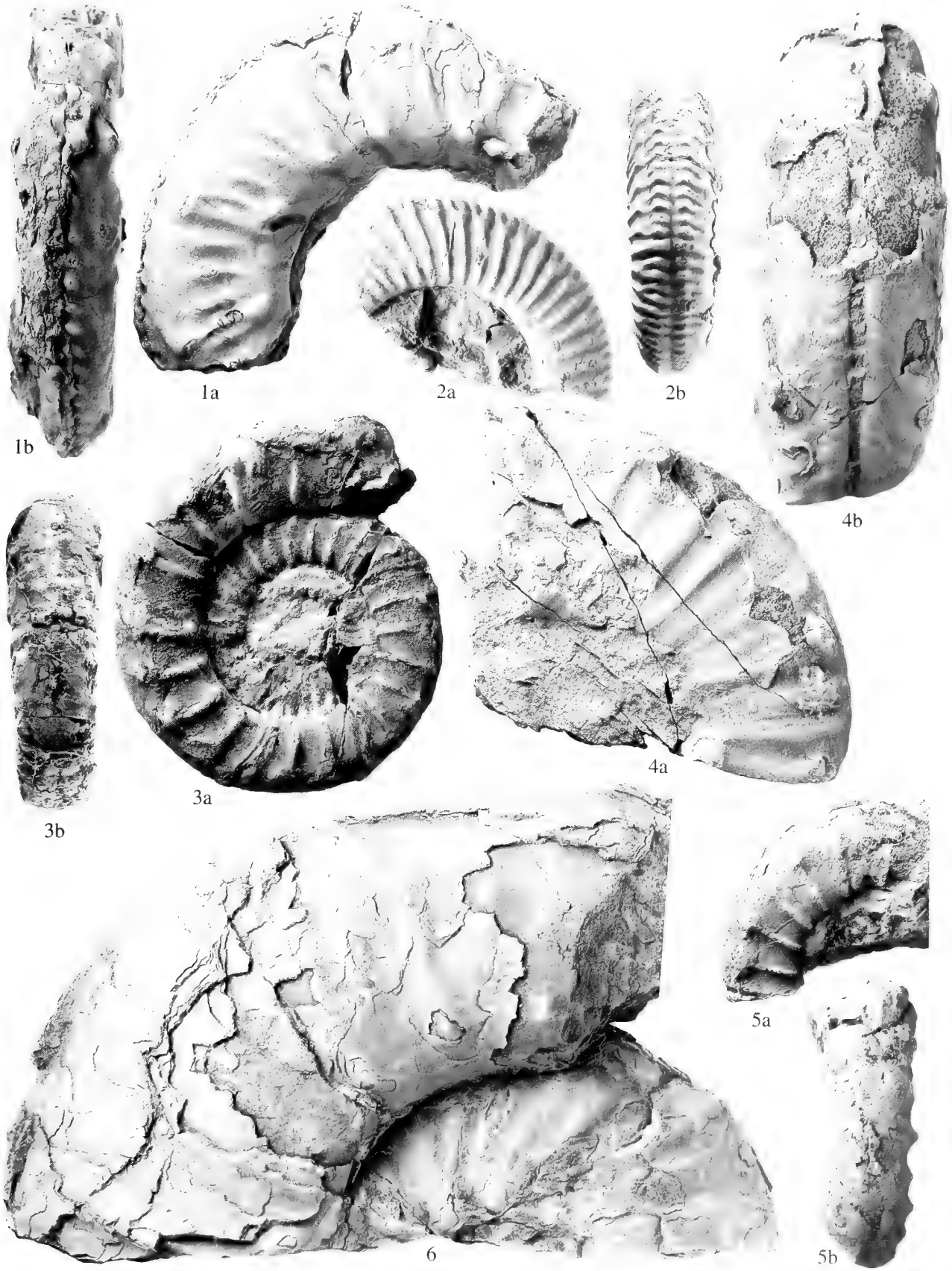
Fig. 1 *Hybonoticeras ornatum* (Spath), upper marly part of Kilya Member (fauna 8), Wadi Kilya. **1a, 1b,** CA1260.

Fig. 2 *Micracanthoceras fraudator* (Zittel), microbialite boulders, Arus Member (fauna 9), east cliff, Wadi Arus. **2a, 2b,** CA771, body-chamber.

Figs 3, 5 *Baeticoceras morrisi* sp. nov., microbialite boulders, Arus Member (fauna 9), west cliff, Wadi Arus. **3a, 3b, holotype**, CA765; **5a, 5b, paratype**, CA766.

Fig. 4 *Hybonoticeras* cf. *hybonotum* (Oppel), upper marly part of Kilya Member (fauna 8), Wadi Kilya. **4a, 4b,** CA1262, wholly septate.

Fig. 6 *Simaspidoceras argobbae* (Dacqué), 16.5 m above base of lower marly part of Kilya Member (fauna 7), Naifa Cliff, CA1045, ×0.56.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1b
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2b
3a
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4a
4b
5a
5b
6

Family **SIMOCERATIDAE** Spath, 1924a
Genus ***PSEUDOCLAMBITES*** Spath, 1925

TYPE SPECIES. *Pseudoclambites aenigmaticus* Spath, 1925, by monotypy.

REMARKS. This genus was created by Spath (1925: 149) for six poorly preserved ammonites from Bihendula, Somalia. Their horizon was not well recorded, but from other ammonites with which they were probably associated he surmised that their age was Tithonian or younger. Spath was unsure of the affinites of *Pseudoclambites*: although he included the genus in the Berriasellidae as 'incertae sedis', he also discussed its alternative inclusion in the Simoceratidae or the Virgatosphinctinae (as a development of *Anavirgatites*), but did not consider that it could belong to the Spiticeratinae (with *Proniceras*) on account of the different form of its constrictions. Later, another specimen from near Bihendula, described as the new species *Pseudoclambites costatus* Spath (1935: 214), allowed Spath to definitely place the genus in the Simoceratidae, and from the other ammonites with which it was associated in the Gawan Limestone, he could determine its age as Tithonian with more certainty.

The holotype of the new Yemeni species described below is much better than any of the material available to Spath. Its has the same morphological features as Spath's genus, differing only slightly in whorl proportions and details of ribbing, which are not worth more than species distinction. The features that led Spath to place the genus in the Simoceratidae seem to be confirmed by the material from Wadi Arus: the passage of the ribs onto the venter without projection forwards, the broad, shallow ventral sulcus, and especially the constrictions that are parallel with the ribs behind, instead of cutting across the ribs behind at a more prorsiradiate angle, as is characteristic of Spiticeratinae. Nevertheless, the resemblance between *Pseudoclambites* and some species of *Proniceras*, means that consideration should be given to a possible origin of the Spiticeratinae (as the earliest subfamily of the Olcostephanidae) in the Simoceratidae. The date of *Pseudoclambites* in the Microcanthum Zone at the base of the Upper Tithonian in Yemen, also vindicates Spath's ideas of the date of the Somali material.

Pseudoclambites araense sp. nov. Pl. 16, figs 1, 3

DERIVATION OF NAME. After Wadi Arus.

HOLOTYPE. CA747 from the microbialite boulders, 6 m above the base of the Arus Member in the east cliff of Wadi Arus.

PARATYPES. Three specimens, CA748–50, all from the same locality and horizon as the holotype.

OTHER MATERIAL. Fragments of 13 specimens (CA752–64) from the same horizon and locality as the holotype, and a fragment of a very large specimen (CA751) from the same horizon in the west cliff in Wadi Arus.

DIAGNOSIS. Evolute, slightly compressed whorls, with a broad, shallow sulcus in the middle of a flat venter. Ribs sharp, prorsiradiate and bifurcating on inner whorls, fading to leave outer whorls smooth except for clavi at the umbilical edge.

DESCRIPTION. The holotype is the only specimen that is well preserved; all the others are fragments and most have rough eroded, surfaces. The holotype has a possibly complete and adult aperture at 104 mm diameter, and its final septum is exactly one whorl before the aperture; its measurements are: at 97.5 mm diameter: 31.5 (0.32), 26.8 (0.28), 40.7 (0.43). The largest paratype (CA749) is 240 mm diameter, in three large pieces, and has traces of septa up to a diameter of about 125 mm at 1.2 whorls before the aperture, but none are visible on the final whorl. The second paratype (CA748) is a complete ammonite 121 mm diameter, but it is very roughly preserved and septa and suture-lines are not visible. The third paratype (CA750) is part of a body-chamber about one-third of a whorl long and 120 mm diameter; it is uncrushed, has parts of the inner whorls attached and is very similar to the holotype; at a whorl height of 34 mm, the whorl breadth is 29.5 mm. The other 13 specimens are fragments of phragmocones and body-chambers, including (CA751) part of a large smooth body-chamber at about 200 mm diameter.

The whorls are evolute and slightly compressed, with a rounded umbilical edge, whorl sides that converge to a smoothly rounded ventro-lateral area, then a flat venter with a broad, shallow sulcus in the middle. Ribs on the inner whorls are sharp and prorsiradiate, then become raised into radial clavi at the umbilical edge and much reduced on the middle and outer part of the whorl from about 60 mm diameter; they then gradually disappear leaving the clavi, which become more widely spaced and nodular. There are two or three secondary ribs for each primary rib, which appear on the outer part of the whorl by indistinct division of the primaries or by intercalation. The ribs pass onto the venter radially without any forwards inclination, and there is a broad, very shallow, smooth sulcus in the middle of the venter. There are 4 or 5 narrow constrictions per whorl, following the line of the primary ribs exactly. At large sizes the ribs tend to be further effaced, leaving only umbilical clavi, traces of the secondary ribs at the sides of the venter, and occasional constrictions. Details of suture-lines are not visible.

REMARKS. *P. araense* is characterized by Perisphinctid-like inner whorls, which become progressively smoother from 60 mm diameter, umbilical edge clavi, and a shallow ventral sulcus that is exactly the same as in Spath's Somali material. It is slightly more evolute, has more compressed whorls and probably a higher rib-density on the inner whorls than *P. aenigmaticum*. *P. costatum* Spath has stronger, more widely spaced ribs, and no clavi at the umbilical edge. Despite its Simoceratid features, *P. araense* has considerable similarities with *Spiticeras (Negreliceras) singulare* Leanza (1945: 79, pl. 15, figs 1, 6; pl. 17, figs 1, 6, 7, 9) (especially pl. 17 fig. 1), which is accepted as an Upper Berriasian species of *Spiticeras* in Argentina by Leanza (1981b: 570).

OCCURRENCE. Microbialite boulders, Arus Member, Hajar Formation, Wadi Arus; Microcanthum Zone, Upper Tithonian.

PLATE 16

Figs 1, 3 *Pseudoclambites araense* sp. nov., microbialite boulders, Arus Member (fauna 9), east cliff, Wadi Arus. **1a, 1b, holotype,** CA747; **3a, 3b, paratype,** CA750, body-chamber.

Fig. 2 *Virgatosimoceras broilli* (Schneid), microbialite boulders, Arus Member (fauna 9), west cliff, Wadi Arus. **2a, 2b,** CA767.

Fig. 4 *Spiticeras (Spiticeras) subspitiense* (Uhlig), bed 34, Mintaq Member (fauna 13), Mintaq Salt Dome. **4a, 4b,** CA597, body-chamber.

Fig. 5 *Spiticeras (Negreliceras) paranegreli* Djanélidzé, bed 31, Mintaq Member (fauna 13), Mintaq Salt Dome. **5a, 5b,** CA607.

Fig. 6 *Spiticeras pricei* sp. nov., bed 60, Mintaq Member (fauna 13), Mintaq Salt Dome. **6a, 6b, paratype,** CA630.


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2a
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3b
4a
5a
5b
6b
6a
4b

Genus ***BAETICOCERAS*** Geyssant, 1979

TYPE SPECIES. *Baeticoceras baeticum* Geyssant, 1979.

Baeticoceras morrisi sp. nov. Pl. 15, figs 3, 5

ETYMOLOGY. After Dr Noel Morris who accompanied the author to Yemen and collected many ammonites.

HOLOTYPE. CA765 from the microbialite boulders, Arus Member, west side of Wadi Arus.

PARATYPE. CA766 from the same horizon and locality as the holotype.

DIAGNOSIS. Characterized by rounded-quadrate whorls of approximately equal whorl height and breadth, and a broad, slightly arched venter. Ribs are single up to 75 mm diameter, fine on inner whorls, rapidly becoming more widely spaced from 40 mm diameter. Ventro-lateral tubercles become obliquely clavate at larger sizes, and there are 3–5 narrow constrictions per whorl.

DESCRIPTION. The holotype is complete and moderately well-preserved up to its maximum size of 74 mm diameter. The paratype is a quarter-whorl fragment at about 64 mm diameter, with part of its next inner whorl attached, and is similarly preserved. Traces of suture-lines can be seen in a few places on the inner whorls of the holotype, but neither suture-lines nor septa can be seen on the outer whorl, or on the paratype. Measurements of the holotype are: at 60.5 mm diameter: 16.5 (0.27), 16.6 (0.27), 31.3 (0.52). The paratype has a whorl height of 15.6 mm and whorl breadth of 16.4 mm, at a diameter of approximately 61 mm. The whorls are very evolute, and the whorl section is rounded-quadrate, with a broad, but slightly arched venter. All the ribs are single, and are fine, straight, sharp and slightly prorsiradiate up to 40 mm diameter, then become progressively more widely spaced at larger sizes. The holotype has 36 ribs per whorl at 35 mm diameter, 32 ribs at 54 mm, and 26 ribs at 65 mm. Prominent ventro-lateral tubercles appear on each rib from 35–40 mm diameter, and from 60 mm diameter they become slightly clavate in an oblique direction. There are 3–5 narrow contrictions per whorl between prominent gently curved ribs in front and behind.

REMARKS. *Baeticoceras* is the youngest genus of the Simoceratidae. It is confined to the Microcanthum Zone, and the earliest species, *B. principale* Geyssant, was probably derived from the last species of *Simoceras*, *S. volanense* (Oppel), at the top of the Ponti Zone, Lower Tithonian. Five species of *Baeticoceras* were described by Geyssant (1979) from the Microcanthum Zone of the Bétic Cordillera in SE Spain, and there are undescribed records from Algeria, Sicily and northern Italy (Geyssant, 1979: 34). *Baeticoceras* has the ribs, ventro-lateral tubercles and constrictions of the family Simoceratidae, and is characterized by the progressively earlier development of primary ribs looped in pairs to ventro-lateral tubercles. In the oldest species, *B. principale*, looped ribs do not appear until the final whorls from a diameter of about 98 mm, and the inner whorls retain the dense, sharp, single ribs of the ancestral *Simoceras*. The new Yemeni species differs in having thicker whorls, where the whorl height and breadth are approximately equal, compared to the much more compressed whorls of *B. principale*, and the ribs on the inner whorls are denser and sharper than in the latter species. The two specimens found so far are smaller than the size at which looped ribs commence in *B. principale*. It appears to be morphologically more primitive than the latter species. Its inner whorls are finely ribbed and lack umbilical tubercles, and are reminiscent of the inner whorls of *Simoceras volanense* (eg. in specimens figured by Santantonio, 1986: 19, fig. 4, pl. 3, fig. 2). As a possible intermediate between *S. volanense* and *Baeticeras principale*, it is good evidence for the basal Microcanthum Zone age of the microbialite boulders in the Arus Formation. Some species of *Tithopeltoceras* Arkell, 1953 (?Himalayitidae), which occurs mainly in the middle part of the Microcanthum Zone, are similar to *Baeticocas*. The nearest is *Tithopeltoceras primus* Oloriz & Tavera (1979: 141, pl. 2, fig. 2), but it and all other species of *Tithopeltoceras* have more depressed whorls (Wh/Wb always <1, usually 0.8–0.5) and larger ventro-lateral tubercles.

OCCURRENCE. Microbialite boulders, Arus Member, Hajar Formation, Wadi Arus; basal Microcanthum Zone, Upper Tithonian.

Genus ***VIRGATOSIMOCERAS*** Spath, 1925

TYPE SPECIES. *Simoceras rothpletzi* Schneid, 1915.

REMARKS. Two examples of *Virgatosimoceras* have been found in the Hajar Formation in Wadi Arus. One is described below as *V. broilii*. The other is a poorly preserved external mould of an ammonite (SM F.12160, Beydoun's field no. ZB703) found in Wadi Arus loose in the scree below the Mintaq Member. It is preserved on a piece of heavy grey limestone typical of that member, but its exact horizon is not known. It shows remains of evolute whorls up to about 130 mm diameter, and has straight primary ribs that are very widely spaced from the smallest size visible of about 20 mm diameter. In this respect its ribbing is very similar to that of the type species, *V. rothpletzi*, as figured by Schneid (1915: pl. 7, fig. 3). The outer part of the whorl and the venter are not seen, however, and the ammonite, though almost certainly a *Virgatosimoceras*, is not determinable beyond *Virgatosimoceras* sp. indet.

Virgatosimoceras broilii (Schneid, 1915) Pl. 16, fig. 2

1915 *Simoceras broilii* Schneid: 90, pl. 6, fig. 4; pl. 7, fig. 1.

MATERIAL. CA767 from the microbialite boulders, Arus Member, in the west cliff in Wadi Arus.

DESCRIPTION. This is a fairly well-preserved specimen, 83 mm diameter maximum size; it has evolute whorls, a quadrilateral whorl section, nearly flat whorl sides and an arched venter; no clear ventral groove can be seen, but it is not well preserved at mid venter. Fine, single, straight prorsiradiate ribs on inner whorls, quickly become widely spaced between 50–65 mm diameter; some ribs divide into 2 or 3 secondaries from 65 mm diameter, and at larger sizes the venter appears to become smooth. No suture-lines are visible.

REMARKS. In whorl proportions and type and density of ribs this ammonite compares well with Schneid's (1915: pl. 7, fig. 1) type specimen. *Virgatosimoceras rothpletzi* (Schneid, 1915: 88, pl. 4, fig. 1; pl. 7, figs 2, 3) is much more coarsely ribbed from 30 mm diameter, and has a ventral interruption of the ribs up to 60 mm diameter, which is lost at larger sizes, while *S. broilii* has Perisphinctid-like ribbing to a much larger size. Jeletzky (1989: 157) recorded *V. broilii* in the Lower Tithonian up to the top of the Semiforme Zone, but in the microbialite boulders of the Arus Member the Yemeni ammonite has to be basal Microcanthum Zone, Upper Tithonian, in age.

OCCURRENCE. Microbialite boulders, Arus Member, Hajar Formation, Wadi Arus; basal Microcanthum Zone, Upper Tithonian.

Family **HIMALAYITIDAE** Spath, 1925
Genus ***AULACOSPHINCTES*** Uhlig, 1910

TYPE SPECIES. *Ammonites moerikeanus* Oppel, 1863, subsequently designated by Spath, 1924a.

Aulacosphinctes spitiensis (Uhlig, 1910) Pl. 13, fig. 3

1910 *Perisphinctes (Aulacosphinctes) spitiensis* Uhlig: 351, pl. 33, figs 1, 3; pl. 41, fig. 1.
1960 *Aulacosphinctes* cf. *spitiensis* Uhlig var. *multicostata* Collignon: pl. 170, fig. 712.

MATERIAL. CA768 from the microbialite boulders, Arus Member, east side of Wadi Arus.

DESCRIPTION. A small specimen, 51 mm diameter, with parts of the umbilical wall preserved up to about 60 mm diameter. The last suture is 0.75 whorls before the present aperture, so it may have had about one whorl of body-chamber when complete. The whorls are evolute and have a subquadrate whorl-section. The primary ribs are sharp and well spaced, and most of them bifurcate on the outer half of the whorl side; there are about 15 primary ribs per half whorl at 43 mm diameter. The secondaries are angled forwards over the arched venter, and there is a well-formed groove in the centre of the venter.

REMARKS. This single ammonite is closely similar to the smallest and best-preserved of Uhlig's (1910: pl. 33, fig. 1) original specimens, which were from the Upper Tithonian of Spiti. The ammonite from the Upper Tithonian of Madagascar that Collignon (1960: fig. 712) figured as var. *multicostata* also appears to be the same, while the specimen that he (Collignon, 1960: fig. 718) determined as *Aulacosphinctes* cf. *spitiensis* is more involute and his finer primary ribs.

OCCURRENCE. Microbialite boulders, Arus Member, Hajar Formation, Wadi Arus; Microcanthum Zone, Upper Tithonian.

Aulacosphinctes natricoides (Uhlig, 1910) Pl. 13, fig. 2

1910 *Perisphinctes (Aulacosphinctes) natricoides* Uhlig: 355, pl. 32, fig.3; pl. 41, fig. 2.

MATERIAL. Two specimens, CA769–70, from the microbialite boulders, Arus Member, west side of Wadi Arus.

DESCRIPTION. CA769 is 47 mm diameter, CA770 is a short fragment of a whorl of similar size, and the presence or absence of septa cannot be determined in either. The whorls are evolute and have a subquadrate whorl-section. Most of the sharp primary ribs bifurcate near the ventro-lateral angle, though a few remain single; there are about 21 primary ribs per half whorl at 43 mm diameter. The secondary ribs weaken in the centre of the venter, but they are not clearly interrupted.

REMARKS. *Aulacosphinctes natricoides* differs from *A. spitiensis* in having denser primary ribs, and secondary ribs that are more continuous across the venter with only a slight mid-ventral depression. In fact *A. natricoides* is one of the few species of *Aulacosphinctes* that has a poorly developed mid-ventral depression. The ammonite from the Tithonian of Madagascar figured by Collignon (1960: pl. 171, fig. 719) as *A. natricoides* var *obliqua* appears to be too coarsely ribbed to belong to this species.

OCCURRENCE. Microbialite boulders, Arus Member, Hajar Formation, Wadi Arus; Microcanthum Zone, Upper Tithonian.

Genus ***MICRACANTHOCERAS*** Spath, 1925

TYPE SPECIES. *Ammonites microcanthus* Oppel, 1865.

Micracanthoceras fraudator (Zittel, 1868) Pl. 15, fig. 2

1868 *Ammonites fraudator* Zittel: 110, pl. 21, figs 2 (lectotype, designated Sapunov, 1979: 194), 3 (*non* fig. 1).
1890 *Hoplites microcanthus* (Oppel); Toucas: 608, pl. 18, fig. 12.
1939 *Himalayites (Micracanthoceras) microcanthum* (Oppel); Mazenot: 233, pl. 37, fig. 2.
1979 *Himalayites (Micracanthoceras) fraudator* (Zittel); Sapunov: 194, pl. 58, fig. 5.
1982 *Himalayites (Micracanthoceras) fraudator* (Zittel); Nikolov: 213, pl. 77, fig. 2.

MATERIAL. CA771 from the microbialite boulders near the base of the Arus Member, east side of Wadi Arus.

DESCRIPTION. This is a well-preserved, uncrushed fragment of a body-chamber one-third of a whorl long, about 65 mm diameter, and has part of the poorly preserved next inner septate whorl attached; the whorl height and breadth are 16.8 mm and 16.7 mm respectively at the larger end. The whorls are evolute, and the whorl section is subtrapezoidal over the ventro-lateral and ventral tubercles. The primary ribs are strong and slightly curved; they mostly bifurcate at a prominent ventro-lateral tubercle, and the short secondary ribs all end at a prominent ventral tubercle bordering a well-marked mid-ventral groove. A few primary ribs remain single: on the one-third of a whorl preserved, there are 2 single and 13 bifurcating ribs.

REMARKS. In *M. microcanthum*, the type species of *Micracanthoceras*, single and bifurcating primary ribs approximately alternate. *Micracanthoceras fraudator* is closely similar and differs only in having many more bifurcating than single ribs. Both species occur in, and are characteristic of, the Microcanthum Zone, the lower half of the Upper Tithonian.

OCCURRENCE. Microbialite boulders, Arus Member, Hajar Formation, Wadi Arus; Microcanthum Zone, Upper Tithonian.

Genus ***HIMALAYITES*** [Uhlig MS] Boehm, 1904

TYPE SPECIES. *Himalayites treubi* Boehm, 1904, subsequently designated by Douvillé (1912c: 262).

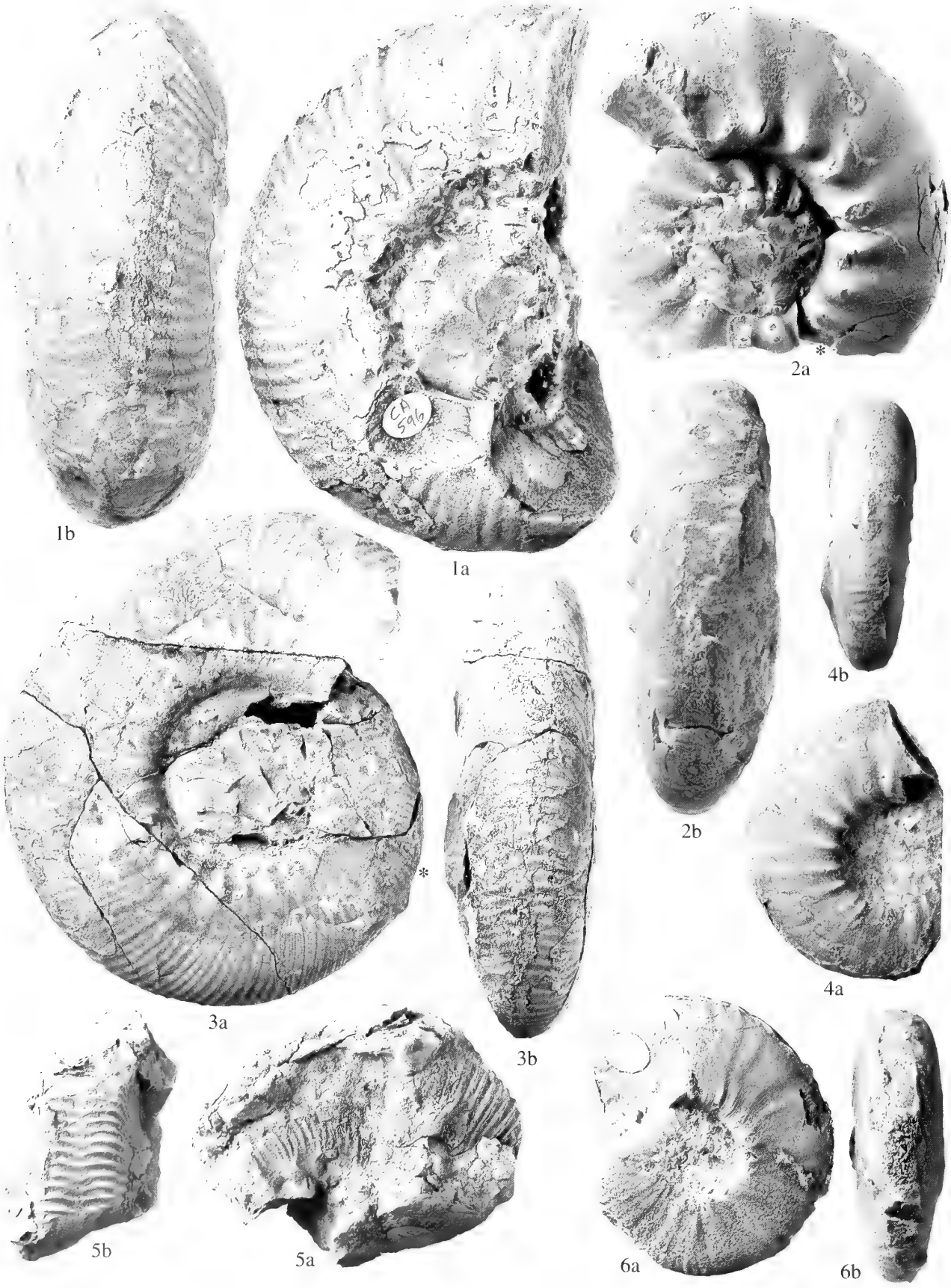
Himalayites sp. indet.

DESCRIPTION. CA772 is a quarter-whorl fragment of one side of a whorl at 80–90 mm diameter, from the microbialite boulders in the Arus Member in the western cliff in Wadi Arus. It has an evolute whorl, a circular whorl section and straight primary ribs, some of which remain single, while others bifurcate or trifurcate at large mid- to ventro-lateral tubercles. This is the morphology of *Himalayites*, which is characterisitic of the Upper Tithonian.

OCCURRENCE. Microbialite boulders, Arus Member, Wadi Arus; Microcanthum Zone, Upper Tithonian.

Family **OLCOSTEPHANIDAE** Pavlow, 1892
Subfamily **SPITICERATINAE** Spath, 1924b
Genus ***SPITICERAS*** Uhlig, 1903
Subgenus ***SPITICERAS*** Uhlig, 1903

TYPE SPECIES. *Ammonites spitiensis* Blanford, 1863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Spiticeras (Spiticeras) spitiense (Blanford, 1863)
Pl. 17, fig. 1

1863 *Ammonites spitiensis* Blanford: 131, pl. 2, fig. 4.
1903 *Holcostephanus (Spiticeras) spitiensis* (Blanford); Uhlig: 89, pl. 8, figs 1–3.
?1922 *Spiticeras* cf. *spitiense* (Blanford); Djanélidzé: 130, pl. 11, figs 1, 2.
1992 *Spiticeras (Spiticeras) spitiense* (Blanford); Howarth: 620, pl. 5, figs 1, 4.

MATERIAL. CA596 from bed 31 of the Mintaq Member, Mintaq Salt Dome.

DESCRIPTION. The outer whorl is 105 mm in diameter and is probably part of a body-chamber because suture-lines appear to be absent; it is moderately involute, with broad rounded whorls, though slightly trigonal in section and very bluntly angled on the venter, and has the following measurements: at 103.0 mm: 36.3 (0.35), 35.8 (0.35), 39.1 (0.38). There are 9 or 10 large umbilical tubercles on the last half whorl; three or four ribs diverge from each tubercle, then swing forwards and form chevrons across the bluntly angled venter.

REMARKS. This is a typical *Spiticeras* with broad rounded whorls, large umbilical tubercles and moderately strong ribbing. It is very similar to the specimen figured by Howarth (1992) from Kurdistan, where its age was shown to be Boissieri Zone, upper Berriasian.

OCCURRENCE. Mintaq Member, Hajar Formation, Mintaq Salt Dome; Occitanica Zone, Berriasian.

Spiticeras (Spiticeras) subspitiense (Uhlig, 1903)
Pl. 16, fig. 4

1903 *Holcostephanus (Spiticeras) subspitiense* Uhlig: 95, pl. 9, fig. 4.

MATERIAL. Two specimens, CA597 from bed 34 and CA598 from bed 69 of the Mintaq Member, Mintaq Salt Dome.

DESCRIPTION. CA597 is half a whorl of incomplete body-chamber, 82 mm diameter; CA598 is 78 mm diameter and probably wholly septate. The involute whorls have a compressed, trigonal whorl section that converges towards a narrowly rounded venter; about 8 large umbilical tubercles per half whorl are elongated radially and pass into poorly defined ribs in the middle of the whorl side; these then divide into many smaller better defined ribs on the outer part of the whorl and pass across the venter angled forwards. One poorly developed constriction occurs on CA597.

MEASUREMENTS

	D	Wh	Wb	U
CA597	82.5	30.0 (0.36)	19.0 (0.23)	29.6 (0.36)
CA598	77.0	29.5 (0.38)	21.6 (0.28)	25.3 (0.33)

REMARKS. The whorls are trigonal in cross-section and more compressed than in *S. (S.) spitiense* and the ribbing is weaker on the middle of the side of the whorls and finer on the venter. Although *S. (S.) spitiense* shows some variation in whorls shape and amount of compression, few are as compressed or as smooth as in *subspitiense*, and the Yemen specimens at least are tending towards the even more compressed and smoother subgenus *Negreliceras*.

OCCURRENCE. Mintaq Member, Hajar Formation, Mintaq Salt Dome; Occitanica Zone, Berriasian.

Spiticeras (Spiticeras) indicum (Uhlig, 1903) Pl. 17, fig. 3

1903 *Holcostephanus (Spiticeras) indicum* Uhlig: 124, pl. 10, fig. 3.

MATERIAL. CA599 and CA600 from bed 31 of the Mintaq Member, Mintaq Salt Dome.

DESCRIPTION. CA599 is a well-preserved, uncrushed ammonite, in which the end of the phragmocone is clearly seen at 70 mm diameter, and is followed by a complete body-chamber, 320° long and 120 mm diameter at the mouth-border of which only a small part is preserved. CA600 is a fragment of a body-chamber, about one-third of a whorl long and 115 mm diameter at its larger end. The whorls are moderately involute, and have an evenly rounded cross-section. There are about 12 small, radially elongated, umbilical tubercles per half whorl at 90–110 mm diameter; four or five radial ribs issue from each tubercle and curve gently forwards across the side of the whorl and meet at an obtuse angle in the middle of the venter.

MEASUREMENTS

	D	Wh	Wb	U
CA599	111.5	38.2 (0.34)	—	41.4 (0.37)
CA599	70.0	27.0 (0.39)	29.8 (0.43)	—
CA600	—	35.7	34.0	—

REMARKS. These specimens have finer ribs and smaller umbilical tubercles than *S. (S.) spitiense* or *subspitiense*. The ribs are also more continuous and persistent, showing no tendency to fade in the middle of the whorl side or near the umbilical tubercles as in most species of *Spiticeras*. *S. (S.) guttatus* (Blanford), *S. (S.) planus* (Uhlig) and *S. (S.) obliquelobatus* (Uhlig), described by Uhlig (1903) from the Spiti Shales, are similar, but all have larger umbilical tubercles, coarser ribs or more compressed whorls. *Spiticeras (S.) multiforme* Djanélidzé (1922: 143), from the Berriasian of SE France, is possibly more similar to the Yemen specimens, but it also has larger umbilical tubercles.

OCCURRENCE. Mintaq Member, Hajar Formation, Mintaq Salt Dome; Occitanica Zone, Berriasian.

Spiticeras (Spiticeras) pricei sp. nov.
Pl. 16, fig. 6; Pl. 17, figs 2, 4, 6; Pl. 18, fig 1, 2

DERIVATION OF NAME. After Dr Ashley Price, BP Exploration Co., who first located the horizon at Mintaq in which it occurs.

HOLOTYPE. CA666 from bed 75 of the Mintaq Member, Mintaq Salt Dome.

PARATYPES. Seven paratypes are designated: CA619. 621, 626

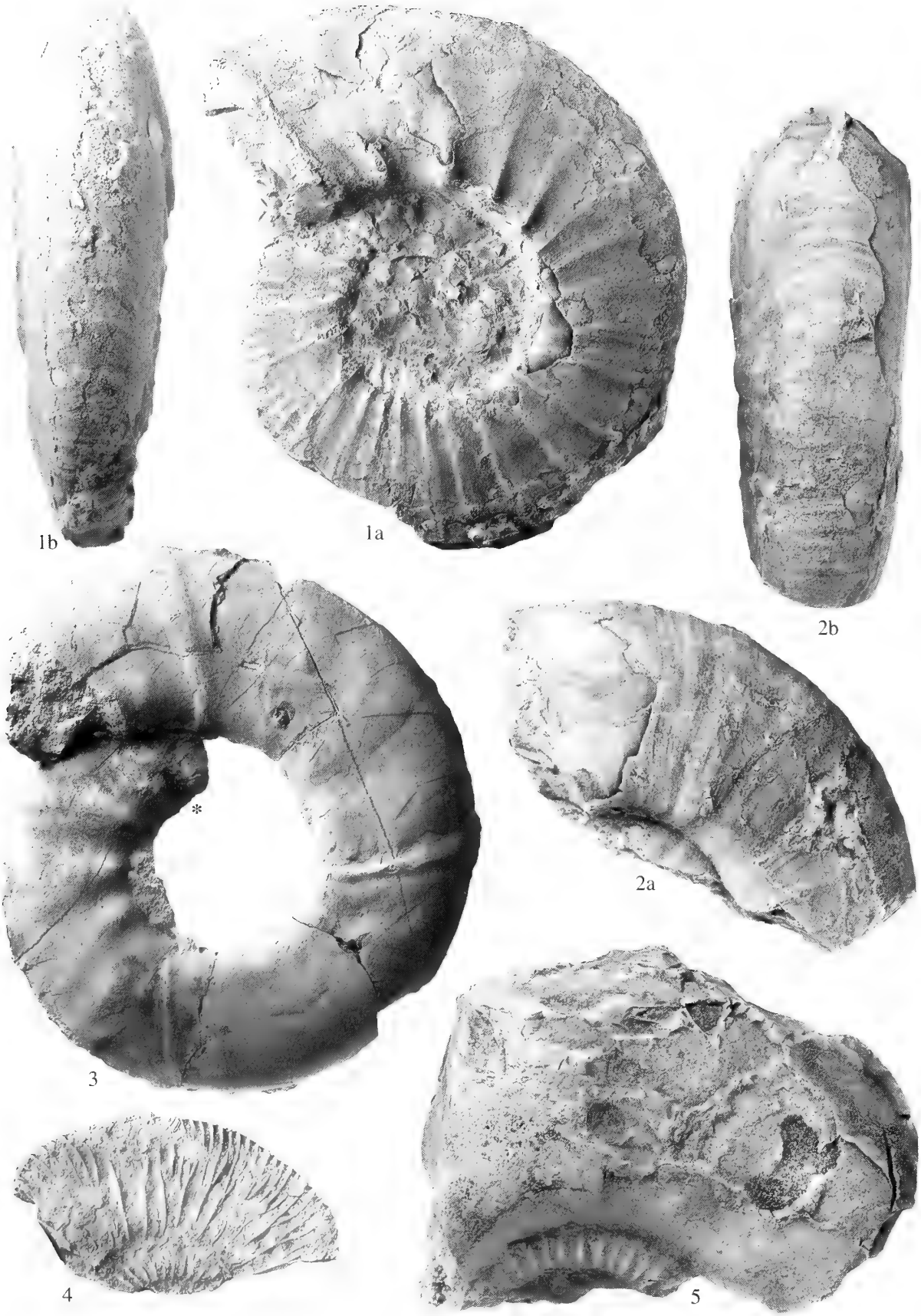
PLATE 17

Fig. 1 *Spiticeras (Spiticeras) spitiense* (Blanford), bed 31, Mintaq Member (fauna 13), Mintaq Salt Dome. **1a, 1b,** CA596, ?body-chamber.

Figs 2, 4, 6 *Spiticeras pricei* sp. nov., **paratypes,** Mintaq Member (fauna 13), Mintaq Salt Dome. **2a, 2b,** CA626 from bed 60 (the asterisk marks the probable end of the phragmocone); **4a, 4b,** CA621 from bed 60; **6a, 6b,** CA663 from bed 69.

Fig. 3 *Spiticeras (Spiticeras) indicum* (Uhlig), bed 31, Mintaq Member (fauna 13), Mintaq Salt Dome. **3a, 3b,** CA599, ×0.78.

Fig. 5 *Spiticeras (Spiticeras) gregoryi* (Spath), microbialite boulders, Arus Member (fauna 9), west cliff, Wadi Arus. **5a, 5b,** CA773.


1b
1a
2b
2a
*
3
4
5

and 628–30 from bed 60, and CA663 from bed 69, from the Mintaq Member, Mintaq Salt Dome.

OTHER MATERIAL. A further 55 specimens were collected: CA608–10 from bed 27; CA611 from bed 29; CA612–13 from bed 30; CA614 from bed 34; CA615–18 from bed 36; CA620, 622–25, 627 and 631–59 from bed 60 (35 specimens); CA660–62 and 664–65 from bed 69; CA667–69 from bed 75; and CA670 from bed 77 in the Mintaq Member, Mintaq Salt Dome.

DIAGNOSIS. The whorls are about half involute, and have a trigonal whorl section with flat converging whorl sides and a flat venter; ornament consists of small to large umbilical tubercles, from which prorsiradiate ribs issue; the ribs fade variably on the side of the whorl; at larger sizes the outer part of the whorl and the venter are smooth except for striae in some specimens.

DESCRIPTION. Many specimens are fragments, and the maximum measurable whorl height is 72 mm, indicating a diameter of about 205 mm, but a fragment of the venter of a body-chamber is from a larger specimen about 250 mm diameter. The holotype is one of three specimens that appear to have complete mouth borders, at 107.5 mm (the holotype), *ca.* 135 mm, and 89 mm diameter respectively; these mouth-borders are slightly flared, but plain, so the specimens are probably macroconchs. Lappets are not preserved in any specimens, and parts of suture-lines are visible only rarely. The whorls are moderately evolute, and the whorl section is characteristically trigonal, with a steep umbilical wall and near-flat whorl sides that converge to a fairly broad flat venter. The ornament is variable: radially elongated umbilical tubercles are typically large and widely spaced, but may be moderate in size or even small in some examples; bold, slightly prorsiradiate, fold-like ribs issue from each tubercle and most of them quickly bifurcate or trifurcate; on the outer half of the whorl one to three secondary ribs may be intercalated between the primary ribs; ribs cross the venter as low undulating folds or striae, or both. In most specimens the ribs are progressively reduced from 60–80 mm diameter, except for a few individuals that retain large single fold-like ribs up to at least 125–130 mm diameter. There are two or three constrictions per whorl following the line of the ribs, but they are not very prominent.

MEASUREMENTS

	D	Wh	Wb	U
CA666, holotype	95.5	34.7 (0.36)	27.7 (0.29)	35.5 (0.37)
CA626, paratype	68.0	25.5 (0.37)	22.2 (0.33)	27.6 (0.41)
CA630, paratype	70.8	27.0 (0.38)	23.1 (0.33)	24.6 (0.35)
CA663, paratype	52.2	21.2 (0.41)	17.6 (0.34)	15.8 (0.30)

REMARKS. With 63 specimens collected, this is the commonest ammonite at Mintaq. It is strangely variable in ornament, and if only 3 or 4 specimens had been collected in isolation, they might well have been given 3 or 4 new specific names. However, the full range of variation occurs at a single horizon (bed 60, from which 41 specimens were obtained), and many intermediates occur between the different morphologies. Perhaps this is the normal range of variation in a species of *Spiticeras*, for which extensive single horizon collections have rarely, if ever, been obtained before.

Spiticeras pricei is similar to *S. laeve* Gerth (1925: 69, pl. 2, fig. 6), which occurs in the Berriasian of Argentina, associated with *Argentiniceras*, but Gerth's species has fewer umbilical tubercles and does not have the trigonal whorl section of *S. pricei*. The smoothest *Spiticeras* in Spiti are *S. subcautleyi* (Uhlig, 1903: 106, pl. 12, fig. 2; pl. 13, fig. 1) and *S. planus* (Uhlig, 1903: 99, pl. 15, fig. 2), but both have more persistent ribbing, especially on the ventral half of the whorl. The converging flat sides and flat venter of *S. pricei* are the same as in *S. gregoryi* Spath (1925: 152, pl. 15, fig. 9) from the Tithonian of Bihendula, Somalia, but the latter has much more persistent and finer ribs on the sides of the whorl and the venter. None of the European *Spiticeras* described by Djanélidzé (1922) and others have the combination of the distinctive whorl section and smooth whorls of *S. pricei*. In the genus *Groebericeras* loss of ornament is taken a stage further, with the whorls becoming entirely smooth in later growth stages, and *S. pricei* might be considered to be a forerunner of that morphology.

OCCURRENCE. Mintaq Member, Hajar Formation, Mintaq Salt Dome; Occitanica Zone, Berriasian.

Spiticeras (Spiticeras) gregoryi (Spath, 1925) Pl. 17, fig. 5

1925 *Bihenduloceras gregoryi* Spath: 152, pl. 15, fig. 9.

MATERIAL. CA773 from the microbialite boulders in the Arus Member on the west side of Wadi Arus.

DESCRIPTION. This is fragment of a whorl at 20–25 mm whorl height and about 70 mm diameter, and part of an inner whorl is attached. It has a quadrilateral whorl section, in which whorl sides converge slightly to a broad, flat venter. Prorsiradiate ribs issue in bundles of 4–6 from large umbilical tubercles; they are continuous across venter with some weakening and a slight backwards bend at the centre. Septa or suture-lines are not preserved.

REMARKS. The features that can be seen on this fragment are identical with those of Spath's unique holotype, except for the very slight backwards bend in the ribs in the middle of the venter. Spath's specimen came from Bihendula, Somalia, not associated with other ammonites and he determined the age as 'Tithonian?' from its morphology.

OCCURRENCE. Microbialite boulders, Arus Member, Hajar Formation, west side of Wadi Arus; Microcanthum Zone, Upper Tithonian.

Spiticeras (Spiticeras) sp. indet.

MATERIAL. Five specimens: CA601–02 from bed 36, CA603 from bed 57 and CA671 from bed 60 of the Mintaq Member, Mintaq Salt Dome; CA859 from a shell bed 26 m above the bottom of the Arus Member, eastern Jebel Billum.

REMARKS. Although these *Spiticeras* are not well enough preserved to be identified specifically, the one from the Arus Member in Jebel Billum is important in providing age information for that level, and the others appear to show the presence of species not otherwise represented in the collections. Thus the two large specimens (CA601–02) from bed 36 in the Mintaq Salt Dome clearly belong to two

PLATE 18

Figs 1, 2 *Spiticeras pricei* sp. nov., Mintaq Member (fauna 13), Mintaq Salt Dome. **1a, 1b, holotype,** CA666 from bed 75, body-chamber. **2a, 2b,** CA661 from bed 69, body-chamber, ×0.80.

Fig. 3 *Spiticeras (Negreliceras) obliquenodosum* (Retowski), bed 36, Mintaq Member (fauna 13), Mintaq Salt Dome, CA604.

Fig. 4 *Virgatosphinctes* cf. *broilii* (Uhlig), shell bed, 26 m above base of Arus Member (fauna 10), eastern Jebel Billum, CA862.

Fig. 5 *Choicensisphinctes limitis* (Burckhardt), 4 m above base of Mintaq Member (fauna 11), eastern Jebel Billum, CA908, ×0.68.

different species. CA601 has a complete, probably adult, mouth-border at 135 mm diameter, thick quadrate whorls, and has umbilical tubercles on the inner whorl, but is smooth from at least 90 mm diameter on its outer whorl; *Spiticeras* is not usually smooth at large sizes, and except for the tubercles on the inner whorls, the morphology is more like that of *Groebericeras*. CA602 is more involute, has a compressed, trigonal whorl section, umbilical tubercles on the inner whorl, and again an apparently smooth outer whorl. The specimen from bed 57 at Mintaq is 80 mm diameter, poorly preserved, and has whorls and tubercles possibly like *S. (S.) spitiense*.

Subgenus ***NEGRELICERAS*** Djanélidzé, 1922

TYPE SPECIES. *Ammonites negreli* Matheron, 1880, subsequently designated by Roman (1938: 382).

Spiticeras (Negreliceras) obliquenodosum (Retowski, 1893) Pl. 18, fig. 3

1893 *Holcostephanus obliquenodosum* Retowski: 249, pl. 9, fig. 18.
1922 *Spiticeras obliquenodosum* (Retowski); Djanélidzé: 178, pl. 11, fig. 4; pl. 20, fig. 3; pl. 21, fig. 6.
1922 *Spiticeras obliquenodosum* var. *fauriensis* Djanélidzé: 181, pl. 21, fig. 7; pl. 22, fig. 2.

MATERIAL. Three specimens: CA604 from bed 36, CA605 from bed 30 and CA606 from bed 29 of the Mintaq Member, Mintaq Salt Dome.

DESCRIPTION. CA604 is a complete body-chamber, 100 mm diameter, in which the umbilical seam uncoils slightly just before the apparently intact mouth-border, which is plain and has no trace of a lateral lappet; it is preserved on one side only, the reverse being crushed and eroded; all the inner whorls are missing; traces of suture-lines suggest that the body-chamber is exactly one whorl long; approximate measurements of CA604: at 97 mm diameter: 33.0 (0.34), –, 37.5 (0.39). The other two are small poorly preserved fragments of single whorls about 60–75 mm diameter and are partly crushed and eroded.

The whorls are compressed, with nearly flat sides and rounded umbilical and ventro-lateral edges; the venter appears to be narrowly rounded, but is not well seen. The smaller specimens have umbilical tubercles, radial ribs of moderate density, and traces of a few constrictions. The body-chamber of CA604 is much smoother: three constrictions remain and there is another (or a collar) at the mouth-border, but the ribs are reduced to indistinct striae, and the umbilical tubercles, which are large and bullate at the beginning of the body-chamber, rapidly disappear on the final three-quarters of a whorl.

REMARKS. Retowski's holotype and the smaller specimens figured by Djanélidzé (1922) are all inner whorls that have ribs and umbilical tubercles, some of which are elongated obliquely backwards. The only larger specimen described hitherto is the 84 mm diameter example figured as var. *fauriensis* by Djanélidzé (1922, pl. 22, fig. 2), which has large umbilical tubercles and reduced ribs on its last quarter whorl, like CA604. As the only larger specimen known, var. *fauriensis* is probably not different from Retowski's species. Few species of *Negreliceras* become smooth in their later growth stages, and this is the only one that combines reduced ribbing with large umbilical tubercles. *Spiticeras altavensis* (Pomel, 1889: 67, pl. 6, figs 1, 2), which has apparently similar tubercles and ribs that fade on the final whorl, might be similar, but it is based on a drawing that cannot be accurately interpreted. *Groebericeras* also becomes smooth at its larger sizes, but the umbilical tubercles disappear as well as the ribs, and it has more involute and massive whorls than the typically compressed and evolute *Negreliceras*.

OCCURRENCE. Mintaq Member, Hajar Formation, Mintaq Salt Dome; Occitanica Zone, Berriasian.

Spiticeras (Negreliceras) paranegreli Djanélidzé, 1922 Pl. 16, fig. 5

1922 *Spiticeras (Negreliceras) paranegreli* Djanélidzé: 108, pl. 6, figs 1–3; pl. 12, fig. 5; pl. 22, fig. 1.

MATERIAL. CA607 from bed 31 of the Mintaq Member, Mintaq Salt Dome.

DESCRIPTION. This is a half whorl fragment, 45 mm diameter, in which septa and suture-lines are not preserved. The whorls are moderately evolute, elliptical in cross-section, with a smoothly rounded umbilical edge and a narrowly rounded venter. The inner part of the side of the whorl is smooth or striate, and fine radial ribs occur only on the outer part of the whorl and the venter. No umbilical tubercles are visible.

REMARKS. This ammonite is very similar to one of the examples figured by Djanélidzé (1922: pl. 6, fig. 1), which has a smooth inner half of the side of the whorl and no umbilical tubercles. Djanélidzé's specimen is a complete microconch, with a long lappet in the mouth-border at 56 mm diameter, which is only a quarter of a whorl larger than the Yemeni specimen. Two other Djanélidzé specimens are complete microconchs at 63 mm diameter and incomplete at 70 mm diameter. *S. (N.) paranegreli* is the only species of the subgenus in which ribs and tubercles are reduced or absent.

OCCURRENCE. Mintaq Member, Hajar Formation, Mintaq Salt Dome; Occitanica Zone, Berriasian.

Family **ATAXIOCERATIDAE** Buckman, 1921
Subfamily **ATAXIOCERATINAE** Buckman, 1921
Genus ***CRUSSOLICERAS*** Enay, 1959, p. 230

TYPE SPECIES. *Ammonites crussoliensis* Fontannes, 1876.

SYNONYM. *Badenia* Enay, 1959, p. 230; type species, *Badenia wegelei* Enay, 1959, p.230 (*nom. nov.* for *Perisphinctes acerrimus* Siemiradzki, Wegele, 1929: 62, pl. 5, fig. 4 (*non* Siemiradzki, 1891)).

REMARKS. *Crussoliceras* is a distinctive genus that is confined to the Divisum Zone at the top of the Lower Kimmeridgian, so its presence in the upper half of the Billum Member is important for dating. The *Perisphinctes*-like primary ribs of the inner whorls become very widely spaced and trifurcate or multiplicate on the outer whorls in *Crussoliceras*, which also has distinctive collared constrictions. The type species of *Crussoliceras* is based on a specimen that is probably a macroconch, while that of *Badenia* is probably a microconch. There are well-formed lappets in some species, eg. in *C. divisum* (Quenstedt, 1888: pl. 106, fig. 1; Geyer, 1961: pl. 3, fig. 5). The similar, but probably unrelated, genus *Katroliceras* of the Hybonotum Zone develops more massive, thicker whorls, and larger primary ribs than *Crussoliceras*.

Crussoliceras cf. *wegelei* Enay, 1959 Fig. 4

1929 *Perisphinctes crussoliensis* Fontannes; Wegele: 61, pl. 6, fig. 1.
1929 *Perisphinctes acerrimus* Siemiradzki; Wegele: 62, pl. 5, figs 4, 5.

Fig. 4 *Crussoliceras* cf. *wegelei* Enay, approximately 8 m below top of Billum Member (fauna 5), 0.5 km NE of river crossing at Al Ma'abir; CA1263, ×0.48 (from a colour photograph taken in the field).

1959 *Badenia wegelei* Enay: 230 (*nom. nov.* for Wegele, 1929: pl. 5, fig. 4, *non Perisphinctes acerrimus* Siemiradzki, 1891).
1961 *Katroliceras (Crussoliceras) tenuicostatum* Geyer: 44, pl. 4, figs 3, 5; pl. 5, fig. 3.

MATERIAL. CA1263 from approximately 8 m below the top of the Billum Member, 0.5 km NE of the river crossing at Al Ma'abir.

DESCRIPTION. This ammonite is on the top surface of a block of fine-grained grey limestone, weathering brown on the outside. It consists of most of a highly evolute outer whorl of 210 mm maximum diameter. The whorl thickness cannot be seen, and removal of part of the very splintery limestone shows that the burried side is not preserved. Widely spaced primary ribs, which tend to curve backwards at their ventral ends on the final third of a whorl, are separated by wide smooth interspaces. The ribs bifurcate or trifurcate at the ventro-lateral edge, and one rib near the beginning of the whorl gives rise to four secondary ribs. There is a constriction half a whorl before the aperture. The inner whorls are not exposed and are not thought to be preserved in the matrix. It is an incomplete macroconch.

REMARKS. This species is characterized by widely spaced primaries that divide into 2 or 3 secondaries at the ventro-lateral edge. One of the specimens figured by Wegele (1929: pl. 6, fig. 1) appears to be an almost complete microconch, while the other specimens of Wegele and Geyer are probably macroconchs, like the Yemen specimen. Geyer (1961: 44) gave a new specific name to his specimen from White Jura γ3 in the Swabian Alb of SW Germany, rather than using Enay's (1959: 230) earlier new name for Wegele's specimen from the Franconian Alb. *C. wegelei* is more evolute, more serpenticone and has less massive whorls than *C. crussoliense* (Fontannes; lectotype refigured by Geyer, 1961: pl. 5, fig. 4), though differences between the two are not large, and intermediates may yet be found. *C. divisum* (Quenstedt, 1888: pl. 106, fig. 1; Geyer, 1961: 44, pl. 3, fig. 5; pl. 5, fig. 1) is more distinct in having more widely spaced ribs from a much earlier growth stage.

OCCURRENCE. Upper part of the Billum Member, Naifa Formation, Al Ma'abir; Divisum Zone, Lower Kimmeridgian.

Subfamily **LITHACOCERATINAE** Zeiss, 1968
Genus ***LITHACOCERAS*** Hyatt, 1900

TYPE SPECIES. *Ammonites ulmensis* Oppel, 1858.

Subgenus ***LITHACOCERAS*** Hyatt, 1900

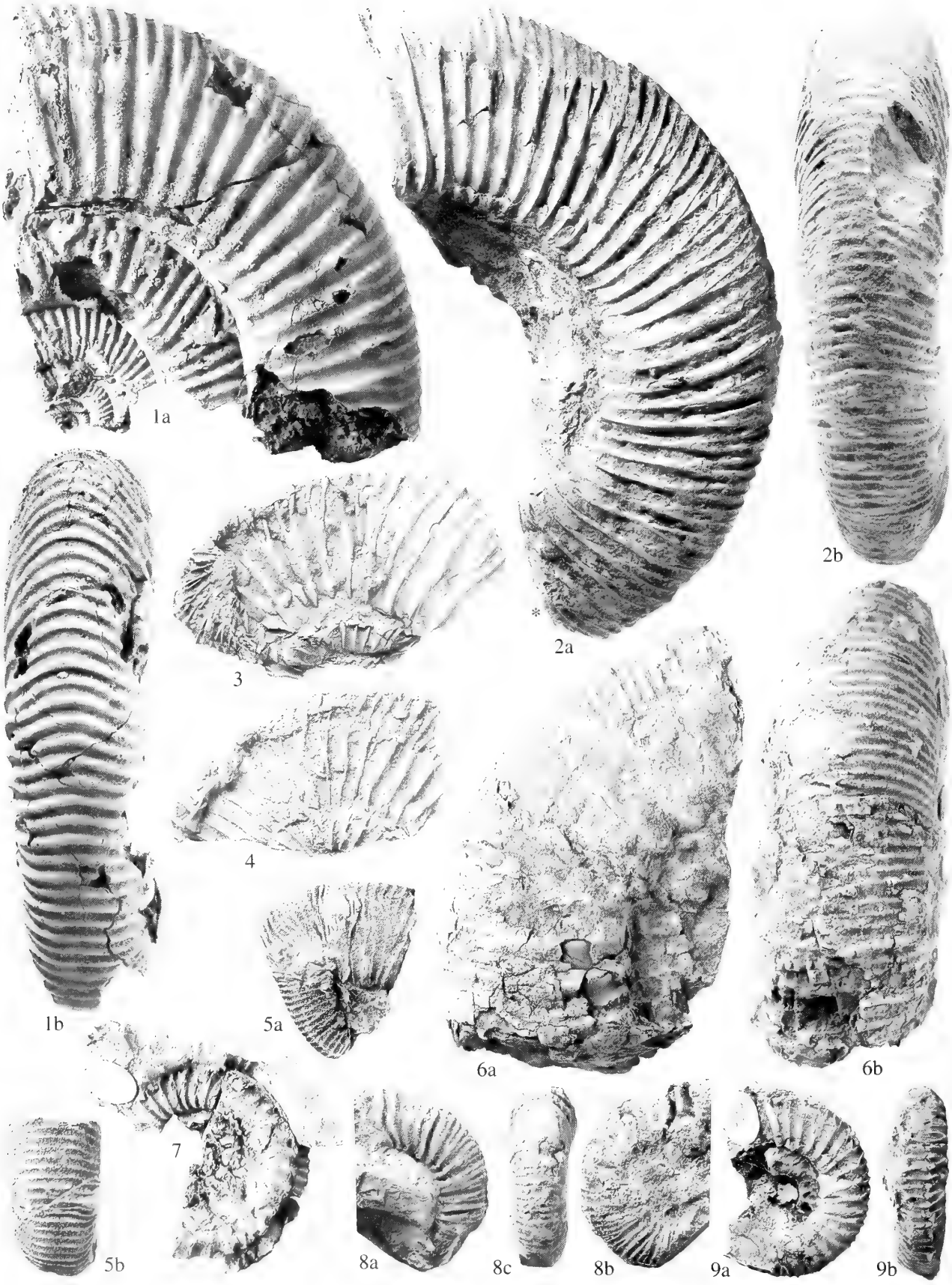
REMARKS. *Lithacoceras ulmense* occurs in the upper half of the Beckeri Zone and the bottom of the Hybonotum Zone on the Kimmeridgian – Tithonian boundary in White Jura ζ in southern Germany (Ziegler, 1977: 23). This is the date of this type species of *Lithacoceras* s.s., and many of the other species from the Upper Oxfordian and throughout the Kimmeridgian that have been referred to *Lithacoceras* in the past are now usually placed in other genera (Zeiss, 1968: 49; Atrops, 1982: 121; Atrops & Melendez, 1993: 20). The lectotype of *L. (L.) ulmense* is a macroconch, and *Lithacoceras* s.s. is used as a subgenus for macroconchs that accompany some of the microconchs of *Lithacoceras (Subplanites)*.

Lithacoceras (Lithacoceras)* cf. *ulmense (Oppel, 1858)
Pl. 19, fig. 6

1858 *Ammonites ulmensis* Oppel: 771.
1863 *Ammonites ulmense* Oppel; Oppel: 261, pl. 74, fig. 1 (*non* figs 2–4).
1914 *Virgatosphinctes (Perisphinctes) ulmensis* (Oppel); Schneid: 159, pl. 4, fig. 3.
1956 *Lithacoceras ulmense* (Oppel); Arkell: 784, pl. 43, fig. 6 (copy of Schneid, 1914: pl. 4, fig. 3).
1957 *Lithacoceras ulmense* (Oppel); Arkell: L323, fig. 413–3 (copy of Schneid, 1914: pl. 4, fig. 3).
1959 *Perisphinctes (Lithacoceras) ulmensis* (Oppel); Berckhemer & Hölder: 52, pl. 10, fig. 50.
1961 *Lithacoceras ulmense* (Oppel); Hölder: 113, pl. 5 (photograph of the lectotype).
1977 *Lithacoceras ulmense* (Oppel); Ziegler: 23, pl. 7, fig. 2.

MATERIAL. Two specimens: SM F.12202 from the base of the middle limestone part of the Kilya Member in Naifa Cliff; and CA1264 from the upper marly part of the Kilya Member in Wadi Kilya.

DESCRIPTION. SM F.12202 is a large quarter-whorl fragment of a body-chamber, of approximately 50 mm whorl height and 49 mm whorl breadth, corresponding to a size of about 160 mm diameter; a small part of the next inner whorl is present in the umbilicus. CA1264 is a poorly preserved phragmocone ending at about 90 mm diameter, to which are attached parts of the body-chamber extending for nearly three-quarters of a whorl further, but the mouth-border is not present. On all whorls the whorl section is smoothly rounded and the venter evenly arched; the inner whorls are compressed, but larger outer whorls are about as thick as high. The ribs are fine and dense on the inner whorls and divide into two or three secondaries; on SM F.12202 the primary ribs become much more widely spaced and


1a
2a
2b
3
1b
4
5a
6a
6b
7
5b
8a
8c
8b
9a
9b

there are many intercalated secondary ribs; in fact 6 primary ribs correspond to 30 secondary ribs on this body-chamber.

REMARKS. In referring Schneid's (1914: pl. 4, fig. 3) finely-ribbed specimen to the same species as Oppel's (1863: pl. 74, fig. 1) lectotype in which the primary ribs become widely spaced at a smaller size, a considerable amount of variation is admitted to *L. (L.) ulmense*. The larger Yemeni specimen (SM F.12202) has widely spaced primaries and 5 times as many secondary ribs, just as on the last quarter-whorl of the lectotype at a similar size. CA1264 from a higher horizon at Al Ma'abir has fine ribs persisting to about 140 mm diameter, and greatly resembles Schneid's specimen. The presence of this well-dated species at Naifa Cliff and Al Ma'abir is confirmation of the zonal age indicated by the accompanying ammonites.

OCCURRENCE. Middle and upper parts of the Kilya Member, Naifa Formation, Naifa Cliff and Wadi Kilya; Beckeri Zone, Upper Kimmeridgian and Hybonotum Zone, Lower Tithonian.

Subgenus ***SUBPLANITES*** Spath, 1925

TYPE SPECIES. *Virgatosphinctes (Perisphinctes) reisi* Schneid, 1915.

REMARKS. The type specimen of the type species of *Subplanites* (Schneid, 1915: pl. 8, fig. 2) is an incomplete microconch, 165 mm diameter. Some authors (Zeiss, 1968: 162–63; Ohmert & Zeiss, 1980: 12) believe that such microconchs commonly accompany the much larger macroconchs of *Lithacoceras* s.s., and *Subplanites* has been given subgeneric status by those who use different names for macroconchs and microconchs in Upper Jurassic ammonites.

Lithacoceras (Subplanites) mombassanum (Dacqué, 1910) Pl. 19, figs 1, 2; Pl. 20, fig. 7

1910 *Lithacoceras (Subplanites) mombassanum* Dacqué: 15, pl. 3, fig. 4; pl. 4, fig. 1.
1925 *Perisphinctes* cf. *abadiensis* Choffat; Stefanini: 148, pl. 27, fig. 3.
1930 *Lithacoceras mombassanum* (Dacqué); Spath: 48, pl. 4, fig. 1.
1930 *Lithacoceras torquatiforme* Spath: 49, pl. 4, fig. 14.
1930 *Lithacoceras mackinnonwoodi* Spath: 49, text-fig. 2.
1930 *Lithacoceras roubyanum* (Fontannes); Spath: 51, text-fig. 3.
1943 *Lithacoceras mombassanum* (Dacqué); Scott: 71, pl. 14, fig. 1.
?1959 *Lithacoceras mombassanum* (Dacqué), var. *antrobikense* Collignon: pl. 90, fig. 359.
non 1959 *Lithacoceras mombassanum* (Dacqué); Venzo: 124, pl. 2, figs 4, 5: pl. 3, fig. 1.
1984 *Lithacoceras? mombassanum* (Dacqué); Verma & Westermann: 49, pl. 8, fig. 1.

TYPE. Spath (1930: 48) designated the original of Dacqué, 1910, pl. 4, fig. 1, as lectotype.

MATERIAL. 38 specimens from the Kilya Member: CA1270 from the upper marly part in Wadi Kilya; CA1265–69 from the middle limestone part in Wadi Kilya; SM F.12198, F.12207, F.13414 and F.16110 from the base of the middle limestone part in Naifa Cliff; 26 (including CA1271–85) from the lower marly part in Wadi Kilya, and SM F.12165–66 from the Breadloaf Concretions in the east cliff of Wadi Arus.

DESCRIPTION. All are fragments or incomplete specimens up to 200 mm diameter. Parts of body-chambers are preserved in some of the uncrushed specimens, but none have any adult features. The 26 specimens from the lower marly part of the Kilya Member in Wadi Kilya are laterally crushed fragments from a shell bed and are from whorls of up to 100 mm diameter. The whorls are slightly involute, and the whorl section is oval and higher than broad. The primary ribs are radial or slightly prorsiradiate, and are straight, but tend to become curved at larger sizes. On whorls of up to 100 mm diameter most of the primary ribs bifurcate high on the whorl side, and the secondaries pass radially over the evenly arched venter without interruption; a very few ribs remain single. At sizes larger than 100 mm diameter, a few ribs trifurcate, or an extra secondary rib is intercalated. Numbers of primary/secondary ribs in six specimens are: 29 primaries/60 secondaries at 185 mm diameter, 35/77 at 130 mm, 12/30 at 160 mm, 14/28 at 128 mm, 20/41 at 100 mm, 15/28 at 90 mm (these are not ribs per whorl; they are counts along different lengths of whorl mostly less than half a whorl long, and the diameters are the approximate sizes at the larger end); the average ratio primaries/secondaries is 1/2.1.

MEASUREMENTS

	D	Wh	Wb	U
SM F.12198	190.0	56.0 (0.29)	48.2 (0.25)	90.0 (0.47)
CA1265	134.5	41.2 (0.31)	34.3 (0.25)	62.0 (0.46)
Lectotype	101.0	31.0 (0.31)	—	45.0 (0.45)

REMARKS. These ammonites are more involute, have more compressed, more rounded whorls, and more primary ribs which occasionally trifurcate, than those species of *Pachysphinctes* that occur at the same horizon. Although none show any adult features, even the biggest of them could be a microconch, which attain very large sizes in some species, eg. the 190 mm diameter microconch with lappets of *Lithacoceras (Subplanites) postrueppelianum* Ohmert & Zeiss (1980: 29, pl. 13, fig. 2). The latter species is from the Hybonotum Zone in south-west Germany, and although closely similar to *L. (S.) mombassanum*, it is more involute, has straighter primaries and many more secondary ribs than the latter species. *L. (S.) mombassanum* is common in the Eudoxus and Beckeri Zones (in the Changamwe Shales) at Mombasa, and it may extend into the Hybonotum Zone (Verma & Westermann, 1984: 49). Another genuine example of the species appears to be the specimen from Ethiopia

PLATE 19

Figs 1, 2 *Lithacoceras (Subplanites) mombassanum* (Dacqué), base of middle limestone part of Kilya Member (fauna 7), Naifa Cliff. **1a, 1b,** SM F.16110a. **2a, 2b,** SM F.12198, body-chamber, ×0.66.

Figs 3, 4 *Berriasella (Berriasella) oppeli* (Kilian), shell bed 26 m above base of Arus Member (fauna 10), eastern Jebel Billum. **3,** CA915. **4,** CA914.

Fig. 5 *Substeueroceras koeneni* (Steuer), shell bed 26 m above base of Arus Member (fauna 10), eastern Jebel Billum. **5a, 5b,** CA940.

Fig. 6 *Lithacoceras (Lithacoceras)* cf. *ulmense* (Oppel), base of middle limestone part of Kilya Member (fauna 7), Naifa Cliff. **6a, 6b,** SM F.12202, body-chamber, ×0.67.

Figs 7, 9 *Berriasella (Berriasella)* cf. *oxycosta* Mazenot, microbialite boulders, Arus Member (fauna 9), Wadi Arus. **7,** east cliff, CA776. **9a, 9b,** west cliff, CA777.

Fig. 8 *Berriasella (Berriasella)* aff. *chomeracensis* (Toucas), bed 60, Mintaq Member (fauna 13), Mintaq Salt Dome. **8a, 8b,** CA673, body-chamber with lappets.

figured by Scott (1943: pl. 14, figs 1, 2), but *L. mombassanum*, var. *antrobikense* Collignon (1959: pl. 90, fig. 359) from Madagascar is more doubtful because of the number of single ribs (30 primaries, 54 secondaries per half whorl at about 80 mm diameter) and its alleged Upper Oxfordian age.

OCCURRENCE. Lower, middle and upper parts of the Kilya Member, Naifa Formation, Wadi Kilya, Naifa Cliff and Wadi Arus; Beckeri Zone, Upper Kimmeridgian, and Hybonotum Zone, Lower Tithonian.

Subfamily **VIRGATOSPHINCTINAE** Spath, 1923a
Genus ***VIRGATOSPHINCTES*** Uhlig, 1910

TYPE SPECIES. *Perisphinctes (Virgatosphinctes) broilii* Uhlig, 1910, subsequently designated by Douvillé, 1912a, p. 737.

Virgatosphinctes* cf. *broilii (Uhlig, 1910) Pl. 18, fig. 4

1910 *Perisphinctes (Virgatosphinctes) broilii* Uhlig: 336, pl. 91, fig. 1.
1971 *Virgatosphinctes* cf. *broilii* (Uhlig); Mouterde: 157, pl. 3, fig. 2.

MATERIAL. 36 specimens: 22 fragments, CA861–82, mainly crushed, from the shell bed, 26 m above base of the Arus Member, and 13 specimens, CA883–95, from a bed of limestone 4 m above the base of the Mintaq Member, both at eastern Jebel Billum; CA775 from the microbialite boulders in the Arus Member in the east cliff of Wadi Arus.

REMARKS. It is not possible to identify this crushed or fragmentary material accurately. They do, however, have the round whorl section and the fine, sharp ribs of *Virgatosphinctes*, which either bifurcate once or twice in virgatotome fashion. In general, the degree of involution of the whorls and the rib density agrees closely with Uhlig's (1910: pl. 91, fig. 1) figure of the holotype of the type species, *V. broilii*, and the secondary ribs appear to pass over the venter with only a slight weakening along the central line.

OCCURRENCE. Arus and basal Mintaq Members, Hajar Formation, eastern Jebel Billum and Wadi Arus; Microcanthum and Durangites Zones, Upper Tithonian.

Genus ***CHOICENSISPHINCTES*** Leanza, 1980

TYPE SPECIES. *Perisphinctes choicensis* Burckhardt, 1903.

Choicensisphinctes limitis (Burckhardt, 1930) Pl. 18, fig. 5; Pl. 20, fig. 9

1900 *Perisphinctes* aff. *erinus* (d'Orbigny); Burckhardt: 42, pl. 26, fig. 3 (photograph of the holotype); pl. 29, fig. 13 (*non* pl. 25, fig. 1, pl. 29, fig. 12 = holotype of *Perisphinctes erinoides* Burckhardt, 1903).
1903 *Perisphinctes* aff. *erinus* (d'Orbigny); Burckhardt: 52, pl. 8, fig. 5; pl. 9, figs 1, 2 (drawing of the holotype).
1930 *Craspedites limitis* Burckhardt: 110 (*nom. nov.* for *Perisphinctes* aff. *erinus* (d'Orbigny); Burckhardt, 1900: 42).
1980 *'Perisphinctes'* aff. *erinus* (d'Orbigny) Burckhardt; Leanza: 35.
1981b *Choicensisphinctes erinus* (Burckhardt, *non* d'Orbigny); Leanza: 571.

MATERIAL. 17 specimens: 8, CA897–904, from the shell bed 26 m above the base of the Arus Formation, and 9, CA905–13, from the limestone 4 m above the base of the Mintaq Member, both in eastern Jebel Billum.

DESCRIPTION. CA905 is an uncrushed quarter-whorl fragment of a phragmocone at about 130 mm maximum diameter, with parts of the inner whorls attached. All the others are less well preserved and often crushed, and most are fragments from a shell bed; two of them are remains of specimens about 200 mm diameter. The whorls are moderately involute and inflated, and have a trapezoidal whorl section in which the rounded whorl sides converge to a rounded venter; the greatest whorl breadth is near the umbilical edge. Sharp ribs on the inner whorls divide into two to six secondary ribs on the outer part of the whorl; occasional ribs are twinned from the umbilical edge. From about 100 mm diameter the primary ribs become widely spaced bulges on the umbilical half of the whorl that are vaguely connected with the many more indistinct secondary ribs that cross the venter; the ribs fade further at larger sizes leaving only bulges on the dorsal half of the whorl.

REMARKS. *Choicensisphinctes* is the generic name given to three closely related species (*C. choicensis* (Burckhardt, 1903), *C. erinoides* (Burckhardt, 1903), and *C. limitis* (Burckhardt, 1930)) that are more involute and more inflated than *Virgatosphinctes*, and tend to become smooth at large sizes, except for large umbilical bulges. *Choicensisphinctes limitis* has the most involute and massive whorls of the three species; it also has a trapezoidal whorl section and loses its ribs more quickly than the others. A feature of *Choicensisphinctes* is that occasional ribs (?one or two per whorl) are twinned from the umbilical edge, as can be seen on several of the specimens figured by Leanza (1980: pl. 3, fig. 1; pl. 4, figs 1, ?3), and also on three of the Yemen specimens (including Pl. 20, fig. 9).

Choicensisphinctes occurs in western Argentina, and apart from a possible record (unfigured) of *C.* cf. *choicensis* in central Turkey (Enay *et al*, 1971: 408) this is the first record from outside Argentina. *Choicensisphinctes* is from the Mendozanus Zone according to Leanza (1980: 13ff; 1981b: 571), which is the lowest part of the Tithonian following the Tithonian transgression in Neuquén and Mendoza. According to Zeiss (1968: 136) this is correlated with the *Parapallasiceras palatinum* Zone in Franconia, which is the top of his Lower Tithonian, below his Middle Tithonian Semiforme (=Bavaricum) Zone. [In the correlation table of Howarth, 1992: 600, table 2, the South American Mendozanus Zone should be correlated with only the top half of the Darwini Zone, because there is no older

PLATE 20

Figs 1, 2 *Berriasella (Elenaella) sevenieri* (Le Hégarat), Mintaq Member (fauna 13), Mintaq Salt Dome. **1a, 1b,** CA674 from bed 36. **2a, 2b,** CA675 from bed 60, ?wholly septate.

Figs 3, 5, 6 *Substeueroceras striatum* sp. nov. **3,** top of bed 1, 25 m above base of Mintaq Member (fauna ?12), Mintaq Salt Dome, CA684. **5, 6, paratypes,** 55 m above base of Mintaq Member (fauna 12), road gorge at southern end of Wadi Arus; 5, CA787, body-chamber with lappet; 6, CA791.

Figs 4, 8 *Malbosiceras* cf. *aizyensis* Mazenot, shell bed 26 m above base of Arus Member (fauna 10), eastern Jebel Billum. **4,** CA932; **8,** CA933.

Fig. 7 *Lithacoceras (Subplanites) mombassanum* (Dacqué), Breadloaf Concretions, Kilya Member (fauna 7), east cliff, Wadi Arus. **7a, 7b,** SM F.12166.

Fig. 9 *Choicensisphinctes limitis* (Burckhardt), 4 m above base of Mintaq Member (fauna 11), eastern Jebel Billum, CA905, wholly septate.


1b


1a *

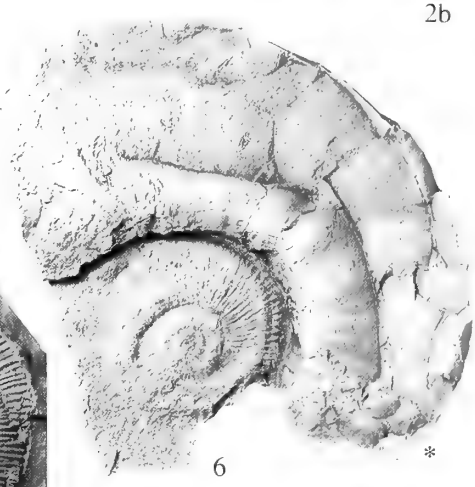

2a


2b


3

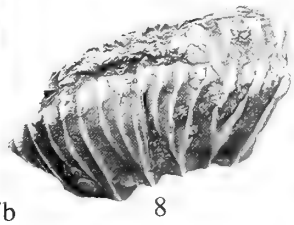

4


5


6 *


7a

7b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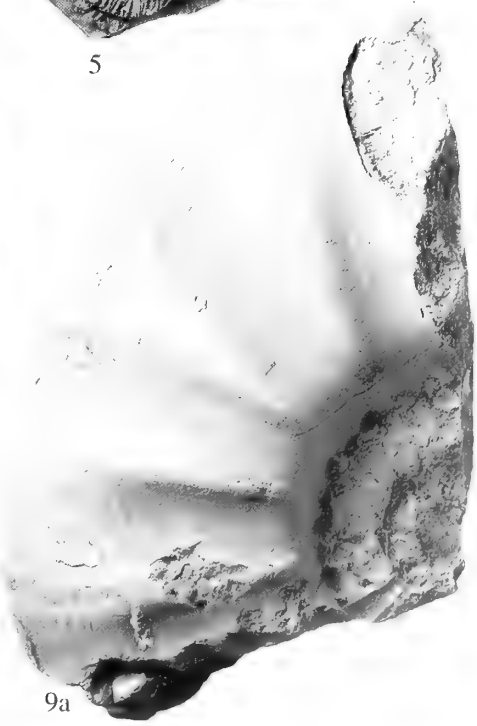
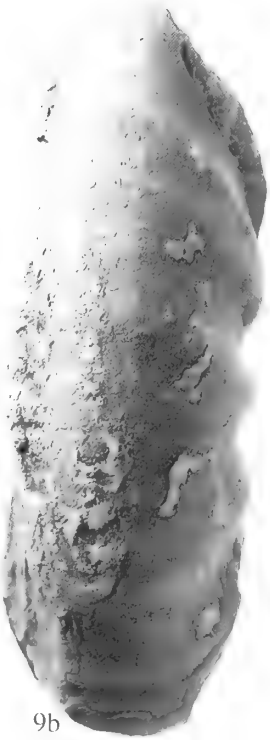

9a


9b

Tithonian in Argentina]. This is a major discrepancy between the age of *Choicensisphinctes* in South America and Yemen, where *C. limitis* cannot be older than Durangites Zone, from the presence of *Spiticeras, Berriasella, Substeueroceras, Blanfordiceras*, and *Malbosiceras* at the same horizon.

OCCURRENCE. Arus and basal Mintaq Members, Hajar Formation, eastern Jebel Billum; Durangites Zones, Upper Tithonian.

Family **NEOCOMITIDAE** Salfeld, 1921
Subfamily **BERRIASELLINAE** Spath, 1922
Genus ***BERRIASELLA*** Uhlig, 1905

TYPE SPECIES. *Ammonites privasensis* Pictet, 1867, subsequently designated by Roman (1938).

SYNONYMS. *Stenoceras* Uhlig, 1911 (type species, *Hoplites storrsi* Stanton, 1896); *Parodontoceras* Spath, 1923a (type species: *Hoplites callistoides* Behrendsen, 1891); *Hegaratella* Nikolov & Sapunov, 1977 (type species, *Berriasella paramacilenta* Mazenot, 1939).

Subgenus ***BERRIASELLA*** Uhlig, 1905

Berriasella (Berriasella) oppeli (Kilian, 1889)
Pl. 19, figs 3, 4

1868 *Ammonites callisto* d'Orbigny; Zittel: 100, pl. 20, figs 1–4.
1889 *Perisphinctes oppeli* Kilian: 662.
1939 *Berriasella oppeli* (Kilian); Mazenot: 49, pl. 3, figs 1–3, 6–8.
1960 *Berriasella oppeli* (Kilian); Drushchits & Kudriavtseva: 275, pl. 20, figs 2. 3.
1973 *Berriasella (B.) oppeli* (Kilian); Le Hégarat: 58, pl. 5, figs 1, 2; pl. 38, figs 4, 5 (see for synonymy).

MATERIAL. 18 specimens, CA914–31, from the shell bed 26 m above the base of the Arus Member, eastern Jebel Billum.

DESCRIPTION. These are all crushed fragments of whorls up to about 28 mm whorl height and 75 mm diameter. Prior to crushing the whorl section appears to have been moderately compressed and with a narrow flat venter. Sharp, straight primary ribs mostly bifurcate on the ventral half of the whorl side, but occasional ribs trifurcate or remain single; the secondaries bend gently forwards near the venter, and a marked interruption can be seen on most specimens in the middle of the venter.

REMARKS. This crushed material from a shell bed represents a species of *Berriasella* closely similar to the type species, *B. privasensis* (Pictet). It differs from the latter mainly in having straight, rather than flexuous, ribs, and a flat, rather than arched, venter. No mouth-borders, lappets or suture-lines are preserved on any of the specimens, but some of the larger ones are probably fragments of body-chambers. *B. oppeli* first appears in the Durangites Zone at the top of the Tithonian and persists into at least the lower half of the overlying Euxinus Zone, according to the records of Le Hégarat (1973: 51, 60) and Nikolov (1982: 56), and it is an important occurrence for the dating of the lower part of the Arus Member in eastern Jebel Billum.

OCCURRENCE. Arus Member, Hajar Formation, eastern Jebel Billum; Durangites Zone, Upper Tithonian.

Berriasella (Berriasella)* cf. *oxycostata Mazenot, 1939
Pl. 19, figs 7, 9

1939 *Berriasella oxycostata* [Jacob MS, 1904; Breistroffer, 1937, *nom. nud.*] Mazenot: 51, pl. 3, fig. 9.
1973 *Berriasella (Picteticeras) oxycostata* (Jacob); Le Hégarat: 78, pl. 8, figs 4–6; pl. 40, figs 2–4.

MATERIAL. Seven specimens, CA776–82, from the microbialite boulders in the Arus Member in Wadi Arus.

REMARKS. These are small specimens and fragments of up to 50 mm diameter. All have fairly evolute whorls, single primary ribs bifurcating at ventro-lateral tubercles, and ventral tubercles bordering a mid-ventral interruption. Two of the better preserved specimens have whorl measurements and sharp ribs very similar to those in *Berriasella oxycostata* as figured by Mazenot, though their fragmentary nature hardly allows a determination more definite than 'cf.' to be made. Mazenot's species occurs in the top of the Tithonian and the bottom of the Berriasian, according to the stratigraphical data of Le Hégarat (1973: 52).

OCCURRENCE. Lower part of Arus Member, Hajar Formation, Wadi Arus; Microcanthum Zone, Upper Tithonian.

Berriasella (Berriasella)* aff. *chomeracensis (Toucas)
Pl. 19, fig. 8

1890 *Hoplites callisto* var. *chomeracensis* Toucas: 601, pl. 17, figs 8, 9.
1939 *Berriasella chomeracensis* (Toucas); Mazenot: 62, pl. 6, figs 1–7.
1973 *Berriasella (Picteticeras) chomeracensis* (Toucas); Le Hégarat: 70, pl. 7, figs 3–5, pl. 39, fig. 12.
1982 *Berriasella (Picteticeras) chomeracensis* (Toucas); Nikolov: 65, pl. 14, figs 1–5.

MATERIAL. CA672 from bed 29 and CA673 from bed 60 in the Mintaq Member, Mintaq Salt Dome.

DESCRIPTION. CA673 is a complete adult microconch with long lappets at 35 mm diameter; CA672 is a half-whorl fragment, slightly larger and incomplete. The whorls are evolute, not compressed, and have a broad rounded venter. The primary ribs are slightly flexuous on the side of the whorl; a few remain single, others bifurcate about the middle of the whorl side, and there are a few intercalated secondaries; they pass across the rounded venter, where there is a mid-ventral interruption. On the last part of the whorl of CA673 there are 12 primary ribs and 24 secondaries.

REMARKS. These small specimens resemble *Berriasella chomacerensis* in whorl shape, rib style (ie. slightly flexuous) and small adult size (one is a complete microconch at 35 mm diameter), but they have fewer single ribs. In SE France, *B. chomacerensis* occurs in the Euxinus Zone (Le Hégarat, 1971: 51), but Nikolov (1982: 65) recorded it at higher levels up to the Boissieri Zone in Bulgaria. Its date in the Occitanica Zone in Yemen is the same as that of *B. privasensis*, which is more involute, has more ribs and attains considerably larger sizes (complete microconchs are 65–75 mm diameter).

OCCURRENCE. Mintaq Member, Mintaq Salt Dome; Occitanica Zone, Berriasian.

Subgenus ***ELENAELLA*** Nikolov, 1966

TYPE SPECIES. *Berriasella cularensis* Mazenot, 1939.

SYNONYM. *Delphinella* Le Hégarat, 1971 (type species, *Hoplites delphinensis* Kilian, 1889).

REMARKS. *Elenaella* differs from *Berriasella* s.s. in having umbilical tubercles and a tendency for the ribs to disappear, at least in the macroconchs. The type species of both *Elenaella* and *Delphinella* conform to this definition, and although the species usually included in *Delphinella* (eg. by Le Hégarat, 1971, and Nikolov, 1982) show these characters more clearly, *Elenaella* has priority.

Berriasella (Elenaella) sevenieri (Le Hégarat, 1973) Pl. 20, figs 1, 2

1973 *Delphinella sevenieri* Le Hégarat: 110, pl. 42, figs 4, 7.
1973 *Delphinella auzonensis* Le Hégarat: 98, pl. 13, fig. 1; pl. 43, fig 1.

MATERIAL. CA674 from bed 36 and CA675 from bed 60 in the Mintaq Member, Mintaq Salt Dome.

DESCRIPTION. CA674 is a fragment of an outer whorl, half a whorl long and about 95 mm diameter. The ribs are prominent at the umbilical edge where they are pinched into small radially elongated tubercles, of which there are 15 on the final half whorl; over most of the side of the whorl the ribs are weak, especially in the middle of the whorl side; near the bluntly angled ventro-lateral edge some ribs can be seen to bifurcate, but they are not visible on the poorly preserved venter. The inner whorls are not visible. CA675 is better preserved with some of its shell replaced with dark red haematite, though considerable areas of the shell surface are missing. It is 60 mm diameter, moderately involute, and has flat whorl sides that converge to a near-flat venter. Sharp primary ribs, which are already weakening on the middle of the whorl side at this size, bifurcate irregularly then pass radially onto the venter which has a central smooth band. There are small umbilical tubercles on each rib.

REMARKS. The holotypes of *D. auzonensis* and *D. sevenieri* do not appear to differ in any respect, and the latter is used as the name for the species because it is based on 12 specimens from known horizons (plus 6 from unkown horizons), whereas the former name is based on a unique holotype for which the horizon was originally not recorded. CA674 is closely similar to that holotype of *D. auzonensis*. In SE France specimens (including the holotype) have been found in the Subalpina and Privasensis Subzones, Occitanica Zone.

OCCURRENCE. Mintaq Member, Mintaq Salt Dome; Occitanica Zone, Berriasian.

Genus ***SUBSTEUEROCERAS*** Spath, 1923a

TYPE SPECIES. *Odontoceras koeneni* Steuer, 1897.

REMARKS. *Substeueroceras* is not known to occur before the middle of the Upper Tithonian, and ranges up into the Berriasian. Verma & Westermann (1973: 228–234) reviewed the occurrences of the genus in Europe and the Americas, and they included *Paradontoceras* as a synonym. They referred many of the figured specimens from Mexico and Argentina to the type species, *S. koeneni* (Steuer), including *S. lamellicostatum* (Burckhardt, 1912: 167, pl. 40, figs 1–4, 6; ?also 1921, pl. 19, figs 9, 10, pl. 20, figs 4–9), of which the lectotype (1912, pl. 40, figs 2–4, 6) is almost identical with Steuer's (1897, pl. 17, figs 1–3) lectotype. A few species are more coarsely ribbed. *Substeueroceras* is similar to the slightly older genus *Kossmatia*, from which it differs mainly in having ribs that pass radially over the venter without the marked forwards pointing inflection of *Kossmatia*. Any mid-ventral groove or interruption of the ribs is confined to whorls up to about 50 mm diameter (eg. Steuer, 1897: pl. 17, figs 4, 5) in *Substeueroceras*, but such a feature remains to much larger sizes in *Kossmatia*.

Substeueroceras koeneni (Steuer, 1897) Pl. 19, fig. 5

1897 *Odontoceras koeneni* Steuer: 45, pl. 17 figs 1–5.
1973 *Substeueroceras koeneni* (Steuer); Verma & Westermann: 240, pl. 48, fig. 5; pl. 49, figs 1, 2 (see for a more complete synonymy).
1992 *Substeueroceras koeneni* (Steuer); Howarth: 638, pl. 1, figs 9, 10; pl. 2, figs 3, ?10.

MATERIAL. 24 specimens: nine, CA940–48, from the shell bed 26 m above the base of the Arus Member in eastern Jebel Billum; two, CA949–50, from the limestone 4 m above the base of the Mintaq Member, and 12, CA951–62, from 9 m above the base of the same member, in eastern Jebel Billum; one, CA685, from bed 60 in the Mintaq Member in the Mintaq Salt Dome.

DESCRIPTION. All the specimens are small fragments of parts of whorls up to about 70 mm diameter. Some are crushed flat, but others are uncrushed and show ribs passing radially across the venter without interruption. The whorls have flattened sides and a nearly flat venter, and the sharp primary ribs that bifurcate once or twice on the sides of the whorl remain prominent up to the largest sizes seen.

REMARKS. These small fragments have ribs like those of the type species of *Substeueroceras*, and do not become striate or smooth on the sides of the whorl as in the new species *S. striatum* described below. Similar fragments occur in the top of the Tithonian in Kurdistan (Howarth, 1992: 638, pl. 1, fig 9, 10, pl. 2, figs 3, ?10; though the venter of one of those specimens (fig. 10) has ribs forming forwardly pointing chevrons and it might be a *Kossmatia*). The extensive synonymy of the Argentinian and Mexican forms given by Verma & Westermann (1973: 229–234, 240) is not repeated here. They discussed the morphological features of these occurrences at length, and it is clear that the Yemeni fragments belong to this fairly variable, moderately strongly ribbed, species of *Substeueroceras*.

OCCURRENCE. Arus and Mintaq Members, Hajar Formation, eastern Jebel Billum and the Mintaq Salt Dome; Durangites Zone, Upper Tithonian, and Occitanica Zone, Berriasian.

Substeueroceras striatum sp. nov. Pl. 20, figs 3, 5, 6; Pl. 21, fig. 1

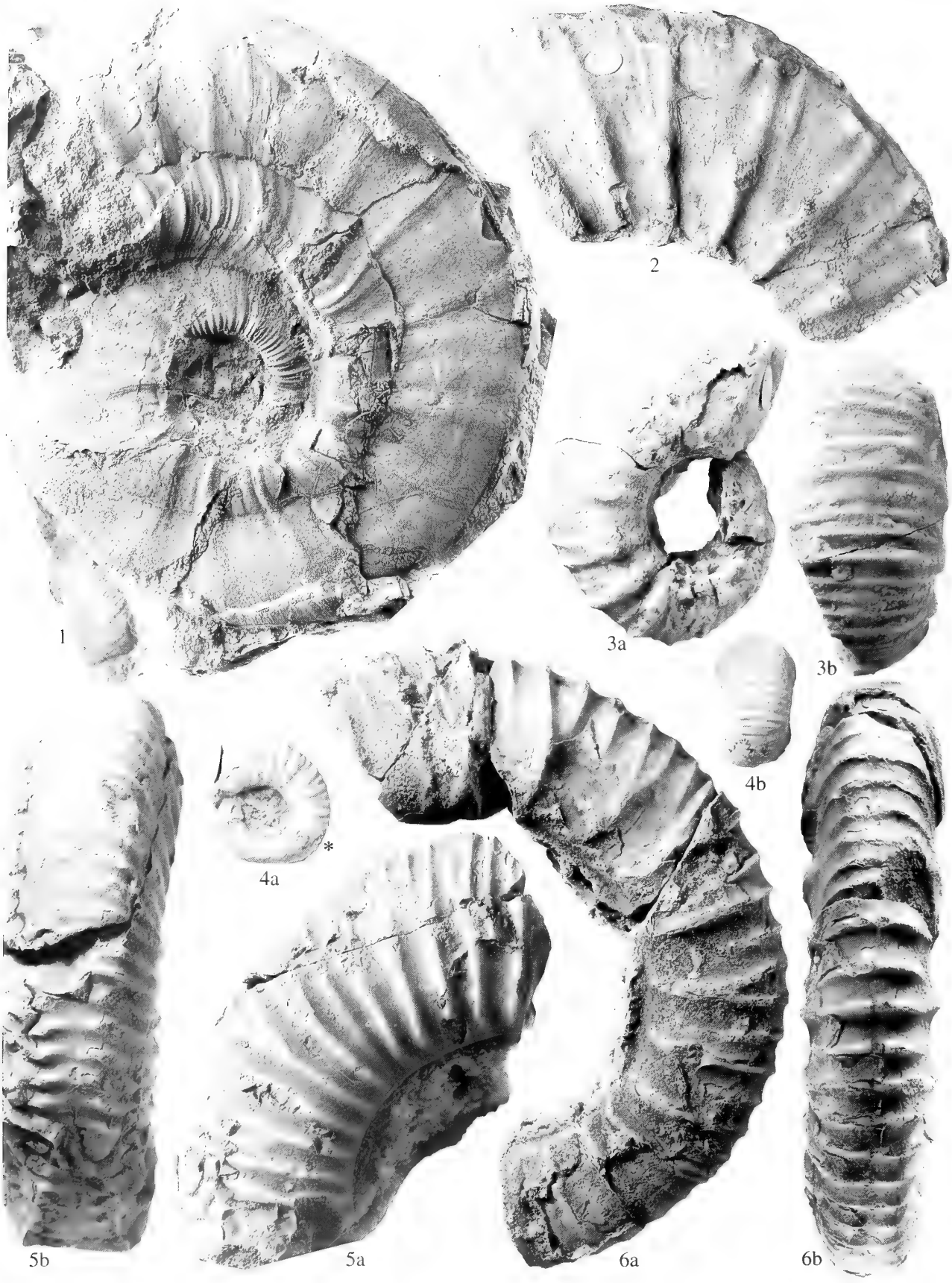
HOLOTYPE. CA963 from the limestone 4 m above the base of the Mintaq Member, eastern Jebel Billum.

PARATYPES. 27 specimens, CA786–810 (CA786 is a slab with three specimens), from a limestone 55 m above the base of the Mintaq Member in the gorge at the southern end of Wadi Arus.

OTHER MATERIAL. Five specimens from eastern Jebel Billum: four, CA964–67, from the same bed as the holotype, and CA968 from 7 m above the base of the Mintaq Member in the same section; and CA684 from the top of bed 1, 25 m above the base of the Mintaq Member in the Mintaq Salt Dome.

DIAGNOSIS. Differs from other species of *Substeueroceras* in reduction of the ribs to striae at 50–75 mm diameter, but the umbilical edge ends of some ribs remain and occasional more widely spaced stronger ribs occur.

DESCRIPTION. The whorls are moderately involute and compressed, with flat sides and rounded umbilical and ventro-lateral edges. The


1
2
3a
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4b
5a
5b
6a
6b

ribs are flexuous, radial, curve forwards slightly at the ventro-lateral angle, and pass radially over the venter without interruption; they bifurcate irregularly at various levels on the side of the whorl, and some bifurcate 2, 3 or 4 times. At 50–75 mm diameter the ribs are reduced to striae, though the umbilical ends remain more prominent and there are occasional irregularly spaced stronger ribs. Most specimens were obtained from the shell bed 31 m below the top of the Mintaq Member exposed on the north side of the road gorge leading south-eastwards out of Wadi Arus. The majority are crushed flat, though some relief remains in the umbilical area in a few specimens. The holotype is from near the base of the thin representative of the Mintaq Member in eastern Jebel Billum, and is the only one to retain substantial relief, although it also is partly crushed laterally. The other specimens from eastern Jebel Billum are more fragmentary than the holotype, though they show the fine ribs that are progressively lost beyond 50 mm diameter; they were found loose, having fallen from the Mintaq Member. The Mintaq Salt Dome specimen (Pl. 20, fig. 3) consists of inner whorls 32 mm diameter that are similar to the Wadi Arus specimens. Dimorphic: the holotype is a macroconch, and is possibly adult and complete at 118 mm diameter; several others are microconchs that retain ribs to the end of growth, and CA787 has a large lappet at 42 mm diameter.

REMARKS. Other species of *Substeueroceras* have stronger ribs remaining to larger diameters. Two specimens from Mexico figured by Burckhardt (1912, pl. 41, figs 3, 4) as *Substeueroceras* sp. indet. are as finely ribbed, but more involute, than the Yemeni species, and a very similar specimen from Somalia was figured by Spath (1925: 146, pl. 15, fig. 3) as *Substeueroceras* sp. indet.

OCCURRENCE. Mintaq Member, Hajar Formation, eastern Jebel Billum, Wadi Arus and the Mintaq Salt Dome; Durangites Zone, Upper Tithonian, ?and Euxinus Zone, Berriasian (see p. 103).

Genus ***RIASANITES*** Spath, 1923a

TYPE SPECIES. *Ammonites rjasanensis* Lahusen, 1883.

SYNONYM. *Tauricoceras* Kvantaliani & Lysenko, 1979 (type species, *T. crassicostatum* Kvantaliani & Lysenko, 1979).

REMARKS. *Riasanites* is a Boreal genus, so the discovery of two examples in the Tethyan Province near the southern border of the Arabian Peninsula is remarkable. Apart from some probable occurrences in Argentina, these are the first *Riasanites* found outside the Boreal Province, and their date at the bottom of the Upper Tithonian is more remarkable. The age of *Riasanites* has been the subject of some debate: after its original description by Nikitin (1888) and Bogoslovsky (1897), it has been generally accepted as a wholly Berriasian, and mainly upper Berriasian, genus, especially by Sazonova (1977: 84) and Kvantaliani & Lysenko (1979). It certainly characterizes a zone (or subzone) in the middle to upper part of the Berriasian in the Volga Basin, the Crimea, the Caucasus and the Caspian areas. However, Arkell (1956: 492–93) thought that the lowest occurrences of *Riasanites* in the Volga Basin might be top Tithonian in age, and in a review of all the occurrences Jeletzky (1984: 236–241) argued that in its type locality (the Central Russian Plain, ie. the Volga Basin) it first occurs at the base of the Riasanian, which is to be correlated with the Upper Tithonian, Transitorius Zone (=Durangites Zone), while the earliest occurrences in Crimea, north Caucasus and Mangyshlak (Caspian) are all younger, in the upper Occitanica and Boissieri Zones, of mid to upper Berriasian age. In these areas, therefore, the total age range of *Riasanites* might be from the top of the Upper Tithonian, Transitorius Zone, to the upper Berriasian, Boissieri Zone. So the discovery of examples of the type species of *Riasanites* at the bottom of the Microcanthum Zone (the bottom of the Upper Tithonian) in Yemen is more than one zone older than the oldest of the occurrences in the Boreal Province, and questions the accepted correlation between Boreal and Tethyan Provinces.

Support for such a date for *Riasanites* is to be found in the only other Tethyan Province occurrences of the genus: in Argentina, H. Leanza (1981a: 78) referred the 22 specimens of *Riasanites* described by Krantz (1928: 25–27, pl. 4, figs 7, 8) to the Koeneni Zone (probably equivalent to the Upper Tithonian Durangites Zone as used here), and A.F. Leanza (1945: 40) described one (unfigured) *Riasanites* from his Alternans Zone (the lower to middle part of the Upper Tithonian). These records in Yemen and Argentina suggest that *Riasanites* was present during much of the Upper Tithonian in the Tethyan Province, an horizon that is older than that of its better known occurrences in the Boreal Province in Russia.

Riasanites rjasanensis (Lahusen, 1883) Pl. 21, fig. 6

1883 *Ammonites rjasanensis* Lahusen [Wenetzky MS]: 69.
1888 *Hoplites rjasanensis* (Lahusen); Nikitin: 91, 188, pl. 1, figs 1–3.
1897 *Hoplites rjasanensis* (Lahusen); Bogoslovsky: 83, pl. 5, figs 3–5.
1977 *Riasanites rjasanensis* (Wenetzky); Sazonova: 85, pl. 18, figs 1–3; pl. 19, figs 1, 2; pl. 20, figs 2, 6; pl. 21, fig. 13.
1979 *Tauricoceras crassicostatum* Kvantaliano & Lysenko: 630, pl. 1, figs 1, 2.

MATERIAL. Two specimens, CA783–84, from the microbialite boulders near the base of the Arus Member in the cliff on the west side of Wadi Arus.

DESCRIPTION. The larger specimen (CA783) consists of half a whorl of body-chamber, 122 mm diameter at its larger end. It has no septa and appears to be incomplete at both ends. All the inner whorls are missing except for some small fragments of the venter of the next inner whorl attached to the dorsum of the body-chamber. The whorl section is slightly compressed, and has flat whorl sides that converge to a narrow, almost flat venter. The whorl measurements are: at 119.5 mm diameter: 33.0 (0.28), 26.5 (0.22), 62.0 (0.52). Widely spaced,

PLATE 21

Fig. 1 *Substeueroceras striatum* sp. nov., **holotype,** 4 m above base of Mintaq Member (fauna 11), eastern Jebel Billum, CA963 most of outer whorl is body-chamber.

Fig. 2 *Malbosiceras* sp. indet., bed 36, Mintaq Member (fauna 13), Mintaq Salt Dome, CA686, ×0.69, body-chamber.

Fig. 3 *Cheloniceras (C.) cornuelianus* (d'Orbigny), upper half of Qishn Formation (fauna 16), Wadi Masila, 220 km ENE of Mukalla; Upper Aptian. **3a, 3b,** C.86982, septate up to just before the aperture.

Fig. 4 *Cheloniceras (C.)* sp. indet., upper half of Qishn Formation (fauna 16), Wadi Masila, 220 km ENE of Mukalla; Upper Aptian. **4a, 4b,** C.86983, possibly a microconch.

Fig. 5 *Blanfordiceras wallichi* (Gray), 4 m above base of Mintaq Member (fauna 11), eastern Jebel Billum. **5a, 5b,** CA969, ?body-chamber.

Fig. 6 *Riasanites rjasanensis* (Lahusen), microbialite boulders, Arus Member (fauna 9), west cliff, Wadi Arus. **6a, 6b,** CA783, body-chamber.

wiry primary ribs, 12 per half whorl at 119 mm diameter, bifurcate irregularly at or just ventral of the middle of the side of the whorl; other secondaries are intercalated, so that 27 secondaries correspond to the 12 primary ribs. The primary ribs are raised but not tuberculate at the point of bifurcation. The secondaries pass over the venter with no forwards projection, and are interrupted or diminish considerably in strength along the mid-ventral line. There are no umbilical, ventro-lateral or ventral tubercles. The second specimen is a short fragment of a body-chamber, and with a whorl height and width of approximately 40 mm and 33 mm respectively (though the dorsal part of the whorl is missing) it is considerably larger than the first specimen. It has more closely spaced ribs than the latter, and so is unlikely to be a larger part of that specimen.

REMARKS. These Yemen examples appear to be the largest *Riasanites* yet found, except for Grigorieva's (1938: 94, pl. 1, fig. 2) *R. rjasanensis* var. *maikopensis* from the Caucasus, which is based on a 138 mm diameter specimen that has more primary ribs (ca.20 per half whorl at 135 mm diameter) than the typical form of *R. rjasanensis*. The Yemen specimen is a close match for the larger specimens figured by Nikitin (1888), Bogoslovsky (1897) and Sazonova (1977), especially in its characteristically narrow, flat venter with the mid-ventral interruption of the ribs, so there can be little doubt that it is conspecific with them. *R. swistowianus* (Nikitin, 1888: 93, pl. 1, figs 5–8) is more evolute, more depressed and has lateral tubercles at the point of bifurcation of the ribs, while *R. subrjasanensis* (Nikitin, 1888: 93, pl. 1, fig. 4; Bogoslovsky, 1897: 87, pl. 5, fig. 6) is more involute, more compressed, has higher whorls and more ribs. *Tauricoceras* Kvantaliani & Lysenko (1979) from the Berriasian of the Crimea is a synonym of *Riasanites*, and its type species, *T. crassicostatum* is so similar to the figured material of *R. rjasanensis*, that the two might even be conspecific. Other species of *Tauricoceras* described by Druschits *et al.* (1984) and Kvantaliani (1989: 15–20, pls 4–12) are based on small specimens that are also very similar to *Riasanites rjasanensis*.

The two figured specimens from the Upper Tithonian of Argentina, *Riasanites rjasanensoides* Krantz (1926: 441, pl. 17, figs 1, 2; 1928: 25, pl. 4, fig. 7), and *R.* aff. *swistowianus* (Nikitin) (Krantz, 1928: 27, pl. 4, fig. 8) are similar and close to the Russian examples, and Leanza (1945: 40) described a single example of *R. rjasanensoides* from the Upper Tithonian, *Corongoceras alternans* Zone, in Mendoza.

Riasanites rjasanensis is somewhat similar to *Argentiniceras mintaqi* sp. nov., which occurs in the Berriasian in the Mintaq Member at the Mintaq Salt Dome, but *Riasanites* differs in having less quadrate whorls, with convergent whorl sides and a narrower venter, a better developed and more persistent mid-ventral interruption of the ribs, and generally more widely spaced ribs, that are never fine and multi-branched as in some species of *Argentiniceras* (eg. *A. mutatum* (Steuer)). *Riasanites* does not develop lateral or umbilical tubercles to the same extent as in some species of *Argentiniceras*.

OCCURRENCE. Lower part of Arus Member, Hajar Formation, Wadi Arus; Microcanthum Zone, Upper Tithonian.

Genus ***BLANFORDICERAS*** Cossmann, 1907

TYPE SPECIES. *Ammonites wallichi* Gray, 1832.

SYNONYMS. *Blandfordiceras* Spath, 1924a, objective synonym; *Pseudoblanfordia* Spath, 1925 (type species, *Hoplites australis* Burckhardt, 1903).

Blanfordiceras wallichi (Gray, 1832) Pl. 21, fig. 5

1832 *Ammonites wallichi* Gray: pl. 110, fig. 3.
1863 *Ammonites wallichi* Gray; Blanford: 84, pl. 15, fig. 1; pl. 19, fig. 1.
1904 *Hoplites wallichi* (Gray); Boehm: 31, pl. 3, fig. 4; pl. 4, figs 1–4; pl.5, fig. 1; text-figs 7–9.
1910 *Hoplites (Blanfordiceras) wallichi* (Gray); Uhlig: 186, pl. 29; pl. 30, fig. 1; pl. 31, figs 1, 2.
1939 *Blanfordiceras* aff. *wallichi* (Gray); Spath: 43, pl. 4, fig. 6; pl. 5, figs 1, 9, 10.
1960 *Blanfordiceras* cf. *wallichi* Uhlig; Collignon: pl. 166, fig. 679.
1971 *Blanfordiceras* cf. *wallichi* Uhlig; Mouterde: 157, pl. 2, fig. 3.
1996 *Blanfordiceras wallichi* (Gray); Wright: 50, fig. 38–1.

MATERIAL. Three specimens: CA969–70 from 4 m above the base of the Mintaq Member, eastern Jebel Billum; CA785 from the microbialite boulders in the Arus Member in the east cliff of Wadi Arus.

DESCRIPTION. CA969 is a well-preserved fragment about one-third of a whorl long and approximately 110 mm diameter at the larger end; there are apparently no septa, so it is probably part of a body-chamber. The whorls are evolute, with a wide umbilicus, a subquadrate whorl section, rounded whorl sides and a flat venter. Strong, straight ribs mostly bifurcate at or just ventral of the middle of the whorl side, but a few ribs remain single; they are projected slightly on the venter, where they end at tubercles bordering a mid-ventral smooth band. CA970 is in a block of hard porcellanous limestone from which it cannot be extracted and shows the characteristic cross-section of a *Blanfordiceras* at about 100 mm diameter. CA785 is only a mould of part of a venter at approximately 100 mm diameter, but it shows the characteristic rows of ventral tubercles bordering a mid-ventral smooth band or slight depression.

REMARKS. *Blanfordiceras* is more evolute and has more quadrate whorls than *Berriasella*, and the ribs on the venter end in small tubercles bordering the mid-ventral smooth band or groove. The Yemeni specimens are close to the holotype of the type species (newly figured by Wright, 1996: fig. 38–1), while many of the other forms from the Spiti Shales described by Uhlig (1910: 186–203) have depressed, massive whorls and tubercles. Eight specimens from Madagascar described by Collignon (1960: pls 166, 167, figs 679–686) include several that are very similar to the Yemeni specimen. Biostratigraphical association with *Kossmatia, Paraboliceras* and *Virgatosphinctes*, and proof that *Blanfordiceras* is Upper Tithonian in age, was obtained by Mouterde (1971: 157) in Nepal.

OCCURRENCE. Arus and Mintaq Members, Hajar Formation, Wadi Arus and eastern Jebel Billum; Microcanthum and Durangites Zones, Upper Tithonian.

Genus ***MALBOSICERAS*** Grigorieva, 1938

TYPE SPECIES. *Ammonites malbosi* Pictet, 1867.

SYNONYMS. *Pomeliceras* Grigorieva, 1938, *non* Hoedemaker, 1981 (type species, *Ammonites breveti* Pomel, 1889); *Mazenoticeras* Nikolov, 1966 (type species, *Berriasella broussi* Mazenot, 1939); ?*Retowskiceras* Nikolov, 1966 (type species, *Perisphinctes andrussovi* Retowski, 1893); *Chapericeras* Hoedemaker, 1981 (type species, *Ammonites chaperi* Pictet, 1868).

REMARKS. Species of *Malbosiceras* are *Berriasella*-like ammonites that develop mid-lateral and umbilical tubercles on periodic

ribs, and have non-tuberculate ribs between. Some species develop more robust, quadrate whorls, some have widely spaced ribs on inner whorls, and the ribs without tubercles may fade at larger sizes. All the synonyms listed above agree with these characters. The biostratigraphic range from Upper Tithonian to the top of the Berriasian is similar to the range of *Berriasella*.

Malbosiceras* cf. *aizyensis Mazenot, 1939 Pl. 20, figs 4, 8

1939 *Berriasella aizyensis* Mazenot: 86, pl. 9, figs 4–6; pl. 10, fig. 1.
1973 *Malbosiceras aizyensis* (Mazenot); Le Hégarat: 82, pl. 9, figs 3, 4.

MATERIAL. Eight specimens, CA932–39, from the shell bed 26 m above the base of the Arus Member, eastern Jebel Billum.

REMARKS. These are all small fragments from ammonites of up to 60 mm diameter. They have widely spaced, wiry primary ribs that divide into 2, 3 or 4 secondaries. The lateral tubercle is just beginning to develop at 50–60 mm diameter, but as in Mazenot's originals it is inconspicuous at these small sizes. All are more coarsely ribbed than *Berriasella (B.) oppeli* which occurs in the same shell bed. *Malbosiceras aizyensis* occurs in the top of the Upper Tithonian in SE France according to the records of Mazenot (1939) and Le Hégarat (1973).

OCCURRENCE. Arus Member, Hajar Formation, eastern Jebel Billum; Durangites Zone, Upper Tithonian.

Malbosiceras sp. indet. Pl. 21, fig. 2

MATERIAL. CA686 from bed 36 in the Mintaq Member, Mintaq Salt Dome.

REMARKS. This is a large quarter whorl fragment of a body-chamber at about 160 mm diameter, that has been crushed obliquely so that the umbilical wall is prominent and the venter mostly missing. The widely spaced ribs have umbilical and lateral tubercles, the latter being on the ventral half of the whorl side. Intercalated ribs are feeble or mostly absent. Large fragments of body-chambers of *Malbosiceras* are not specifically determinable when isolated from their inner whorls. Several have been figured by Mazenot (1939: pl. 11, fig. 3; pl. 12, fig. 5), Le Hégarat (1973: pl. 12, 17, 19) and Nikolov (1982: pl. 54, fig. 2; pl. 58, fig. 1). They occur in the top of the Tithonian and especially in the mid to upper parts of the Berriasian according to Le Hégarat's (1973: 83, 115) and Nikolov's (1982) stratigraphical records.

OCCURRENCE. Mintaq Member, Hajar Formation, Mintaq Salt Dome; Occitanica Zone, Berriasian.

Genus ***PROTACANTHODISCUS*** Spath, 1923a

TYPE SPECIES. *Hoplites andreae* Kilian, 1889.

Protacanthodiscus sp. indet.

MATERIAL. CA687 from bed 149 in the Mintaq Member, Mintaq Salt Dome, and four specimens, CA811–814, from a limestone 55 m above the base of the Mintaq Member in the gorge at the southern end of Wadi Arus.

REMARKS. It is worth recording that ammonites with ventro-lateral tubercles and ribs looped to them in some places accompany *Substeueroceras striatum* sp. nov. in the shell-bed in the Mintaq Member in Wadi Arus. The ribs are fine and similar to those of *S. striatum*, and there appear to be no umbilical or lateral tubercles. The crushed preservaton is not sufficiently good from them to be illustrated or identified, but *Protacathodiscus* seems to be the genus to which they should belong, because ventro-lateral tubercles with ribs looped to them do not occur in either *Berriasella* or *Substeueroceras*. The example from the Mintaq Salt Dome is a poorly preserved, similarly tuberculate specimen.

OCCURRENCE. Mintaq Member, Hajar Formation, Wadi Arus and Mintaq Salt Dome; Durangites Zone, Upper Tithonian, or Euxinus Zone (see p. 103), Berriasian, and Occitanica Zone, Berriasian.

Subfamily **NEOCOMITINAE** Salfeld, 1921
Genus ***ARGENTINICERAS*** Spath, 1924b

TYPE SPECIES. *Odontoceras malarguense* Steuer, 1897.

SYNONYMS. *Andesites* Gerth, 1925 (type species, *Perisphinctes loncochensis* Steuer, 1897); *Boncheviceras* Nikolov, 1966 (type species, *Berriasella ardescensis* Mazenot, 1939).

REMARKS. *Argentiniceras* is essentially a genus from the Lower Berriasian of the Andean Province, and all the figured material comes from western Argentina, though *Argentiniceras* also occurs in Colombia, Peru, and the Antarctic Peninsula according to Wiedmann's (1980: 51, fig. 8) map. Records from outside the Andean Province are few. One of them is the type (and only) specimen of *Berriasella ardescensis* Mazenot, 1939, from the Berriasian of SE France, which was made the type of *Boncheviceras* Nikolov, 1966, and is a coarse-ribbed species similar to *Argentiniceras malarguense*. The only other occurrence is Krishna's (1991) more recent record of two specimens from western India, where they were given a Berriasian date to agree with the date of the genus in South America. Krishna's (1991: pl. 1, figs 1, 2) figured specimen is a close match for the holotypes of *A. malarguense* and *A. loncochense*, having similar coarse secondary ribs and small umbilical tubercles. The six Yemen specimens described here include a new species that has widely spaced primary ribs, as well as an example of the more finely ribbed Argentinian species *A. mutatum* (Steuer).

Argentiniceras mutatum (Steuer, 1897) Pl. 23, fig. 1

1897 *Reineckeia mutata* Steuer: 27, pl. 13, figs 1, 2.

MATERIAL. CA693 from bed 57 in the Mintaq Member, Mintaq Salt Dome.

DESCRIPTION. The specimen consists of a complete body-chamber, 210° long, ending in a plain aperture at 106 mm diameter; inner whorls are not exposed, being filled with recrystallized calcite and covered with limestone matrix that cannot be removed. Whorl measurements at the mouth-border are: at 106 mm: 34.2 (0.32), 36.0 (0.34), 42.5 (0.40). The whorl section is quadrate, with flat sides and venter. Widely spaced primary ribs divide irregularly into secondaries on the upper half of the whorl side, and other secondaries are intercalated. The ribs are continuous across the venter. There are 14 primary ribs and about 40 secondaries per half whorl at 105 mm diameter. There are no true tubercles at the umbilical edge, the slightly greater prominence of the ribs here being mainly due to their diminution in the middle of the whorl side.

REMARKS. This ammonite is closely similar to the inner whorl of the 210 mm diameter holotype of *A. mutatum*, from the Lower Berriasian of NW Agentina. The type species of *Argentiniceras*, *A. malarguense* (Steuer, 1897: 55, pl. 20, figs 1–3), has fewer, coarser ribs and small or incipient umbilical tubercles. The latter are slightly


1a
*
1b
2a
2b
4b
3a
*
3b
4a
5a
*
5b

better developed in *A. loncochense* (Steuer, 1897: 61, pl. 2 figs 1–3), the type species of *Andesites*. *A. fasciculatum* (Steuer, 1897: 64, pl. 3, figs 1–3) is also very similar to *A. malarguense*, and it is probable that *A. loncochense* and *A. fasciculatum* are synonyms of *A. malarguense*. Another species from the same region, *A. noduliferum* (Steuer, 1897: 64, pl. 1, figs 1–4), differs in having small lateral tubercles from about 120 mm diameter. Both umbilical and lateral tubercles are even larger in *A. bituberculatum* Leanza (1945: 48: pl. 8, figs 1, 2) from the same area.

OCCURRENCE. Mintaq Member, Hajar Formation, Mintaq Salt Dome; Occitanica Zone, Berriasian.

Argentiniceras mintaqi sp. nov. Pl. 22, figs 1–4

HOLOTYPE. CA694 from bed 57 in the Mintaq Member, Mintaq Salt Dome.

PARATYPES. CA695 from bed 36 and CA696 from bed 57 in the Mintaq Member, Mintaq Salt Dome.

OTHER MATERIAL. CA697 from bed 60 and CA698 from bed 64 in the Mintaq Member, Mintaq Salt Dome.

DIAGNOSIS. Has approximately 11 primary and 22 secondary ribs per whorl at 100–140 mm diameter, which is fewer than in other species of *Argentiniceras*; there are small, thin tubercles on the ribs at the umbilical edge, and the secondary ribs pass across the venter without interruption.

DESCRIPTION. The holotype consists of a complete body-chamber 135° long and 140 mm diameter at its plain, slightly flared, mouth-border. CA696 is a smaller immature specimen, with half a whorl of body-chamber and a final diameter of 98 mm. CA695 is a fragment of a body-chamber about 60° long and 105 mm diameter. CA697 and CA698 are smaller and less well-preserved, though they both show the primary ribs of the inner whorls. The whorl section is quadrate, with flat whorl sides and slightly arched venter. The widely spaced primary ribs curve slightly backwards and divide into secondaries about the middle of the whorl side, and then pass over the venter without interruption. The ribs are raised near the umbilical edge giving the appearance of slight tubercles, but on the inner whorls of CA697 and CA698 the tubercles are larger. There are 11 primaries and 21 or 22 secondaries on the final half whorl of both the holotype and CA696.

REMARKS. *A. mintaqi* is similar to *A. malarguense* (Steuer, 1897: 55, pl. 20, figs 1–3), but has fewer, more widely spaced ribs that bend slightly backwards on the side of the whorl. It has the typical characters of *Argentiniceras* – quadrate whorl section, bold, mainly bifurcating ribs that are continuous across the venter, and small umbilical tubercles.

OCCURRENCE. Mintaq Member, Hajar Formation, Mintaq Salt Dome; Occitanica Zone, Berriasian.

Genus ***TIRNOVELLA*** Nikolov, 1966

TYPE SPECIES. *Berriasella alpillensis* Mazenot, 1939.

REMARKS. Despite being placed in synonymy with *Subthurmannia* by Wright (1996: 55), it seems to be useful to keep *Tirnovella* distinct on account of it much more involute, more compressed whorls. In this respect it more closely resembles *Subalpinites*, which differs in its stronger ribs and lateral tubercles on later whorls. In its compressed whorls and umbilical tubercles *Tirnovella* is also like *Dalmasiceras*, but the latter loses most of the ribs to become smooth on its flatter whorl side at a much earlier stage than *Tirnovella*.

Tirnovella occitanica (Pictet, 1867) Pl. 22, fig. 5

1867 *Ammonites occitanicus* Pictet: 81, pl. 16, fig. 1.
1939 *Neocomites occitanicus* (Pictet); Mazenot: 213, pl. 33, figs 1–3; pl. 34, figs 2, 3; pl. 35, fig. 1.
1951 *Neocomites occitanicus* (Pictet); Arnould-Saget: p. 81, pl. 7, fig. 8.
1960 *Neocomites occitanicus* (Pictet); Nikolov: 182, pl. 21, figs 1, 2.
1962 *Neocomites occitanicus* (Pictet); Collignon: pl. 179, fig. 797.
1968 *Neocomites occitanicus* (Pictet); Le Hégarat & Remane: 22, pl. 4, fig. 1.
1973 *Tirnovella occitanica* (Pictet); Le Hégarat: 185, pl. 27, fig. 9; pl. 49, fig. 5.
1982 *Neocomites occitanicus* (Pictet); Nikolov: 230, pl. 83, figs 1, 2; pl. 85, fig. 4.

MATERIAL. Two specimens, CA1296–97, from the Mintaq Member, on the top of Jebel Madbi.

DESCRIPTION. CA1296 consists of a body-chamber, ca. 120° long between the last suture-line and the mouth-border at 70 mm diameter. Although apparently complete and adult with somewhat modified ribs on the final part of the body-chamber, there is no sign of a lappet on the mouth-border. Its measurements are: at 68.0 mm diameter: 28.8 (0.43), 19.2 (0.29), 18.8 (0.28). The earlier whorls are preserved in the matrix as recrystallised calcite and are not exposed. CA1297 is less well-preserved and has a maximum size of 98 mm diameter. Both have involute, compressed whorls and a rounded venter. Ribs are bundled in twos or threes to sharp, radially elongated umbilical tubercles; they are gently flexuous on the side of the whorl and pass across the venter with only a slight reduction of relief along the mid-ventral line. On the final 50° of body-chamber of the smaller specimen the ribs are reduced, though there is one 'periodic' heavier rib and another at the mouth-border itself. The larger specimen has coarser ribs, but they are only visible at larger diameters (70–98 mm) than on the smaller specimen.

REMARKS. The better preserved Jebel Madbi ammonite is a good match for the holotype and subsequently figured specimens from SE France. Both ammonites were collected from an unrecorded level in the Mintaq Member on the top of Jebel Madbi. That stratigraphical level is well above the base of the Mintaq Member, and is probably at a higher horizon than that of the main ammonite fauna in the middle of the Mintaq Member in the Mintaq Salt Dome. The age indicated is Occitanica Zone, and might well be high in that zone, if it is younger than the Mintaq Salt Dome fauna.

OCCURRENCE. Mintaq Member, Hajar Formation, on the top of Jebel Madbi; Occitanica Zone, Berriasian.

PLATE 22

Figs 1–4 *Argentiniceras mintaqi* sp. nov., Mintaq Member (fauna 13), Mintaq Salt Dome. **1a, 1b, holotype,** bed 57, CA694, body-chamber, ×0.75. **2a, 2b,** bed 60, CA697. **3a, 3b, paratype,** bed 57, CA696. **4a, 4b, paratype,** bed 36, CA695, body-chamber.
Fig. 5 *Tirnovella occitanica* (Pictet), Mintaq Member (fauna 14), top of Jebel Madbi. **5a, 5b,** CA1296.

Suborder **ANCYLOCERATINA** Wiedmann, 1966
Superfamily **ANCYLOCERATACEAE** Gill, 1871
Family **ANCYLCERATIDAE** Gill, 1871
Subfamily **CRIOCERATITINAE** Gill, 1871
Genus ***CRIOCERATITES*** Léveillé, 1837

TYPE SPECIES. *Crioceratites duvalii* Léveillé, 1837, subsequently designated by Diener, 1925.

Crioceratites (C.)* cf. *villiersianus (d'Orbigny, 1842) Pl. 23, fig. 2

1842 *Crioceras villiersianus* d'Orbigny: 462, pl. 114, figs 1, 2.
1902 *Crioceras villiersianus* d'Orbigny; Sarasin & Schöndelmayer: 107, pl. 12, fig. 3.
1955 *Crioceras villiersianus* d'Orbigny; Sarkar: 65–68, pl. 3, figs 4, 8, pl. 5, fig. 14.
1964 *Crioceras villiersianus* d'Orbigny; Thomel: 21.

MATERIAL. CA1298, found loose immediately below the Qishn Formation in eastern Jebel Billum. The matrix indicates that it came from the 5 m of sandy limestone at the bottom of the Qishn Formation.

DESCRIPTION. The specimen consists of nearly half a whorl from an ammonite of about 90 mm diameter, and the whorl height and breadth at the larger end are 34 mm and 19.5 mm respectively. It is almost uncrushed, having a compressed whorl shape, flat whorl sides and rounded venter, but it cannot be determined whether the whorls were uncoiled or in contact. The ornament consits of fine ribs, that are straight and radial on the side of the whorl, and curve slightly forwards across the venter. Some ribs bifurcate near the umbilicus or at higher levels on the whorl side. Periodically every 8th to 12th rib is stronger or flared, especially near the umbilicus and on the ventro-lateral part of the whorl side. Ventro-lateral tubecles are not seen, possibly due to the poor preservation.

REMARKS. Although this ammonite was found loose just below the base of the Qishn Formation in the cliff section north of the road in eastern Jebel Billum, its sandy limestone matrix matches that of the bottom 5 m of that formation. Its morphological features are like those of the two closely similar species *Crioceratites duvalii* Léveillé and *C. villiersianus* d'Orbigny. Identification with the latter is made on the basis of its ribs that are more numerous and finer than those of the former species. *C. villiersianus* occurs in the upper half of the Hauterivian and possibly just extends into the basal Barremian in SE France according to the records of Sarkar (1955: 67) and Thomel (1964: 71). *C. duvalii* is slightly older in the middle and upper parts of the Hauterivian, and does not extend into the base of the Barremian. So this is an important ammonite for establishing an Upper Hauterivian age for the lower part of the Qishn Formation.

OCCURRENCE. Qishn Formation, lower part, eastern Jebel Billum; Upper Hauterivian.

Order **NAUTILIDA** Agassiz, 1847
Superfamily **NAUTILACEAE** de Blainville, 1825
Family **PARACENOCERATIDAE** Spath, 1927
Genus ***PARACENOCERAS*** Spath, 1927

TYPE SPECIES. *Nautilus hexagonus* J. de C. Sowerby, 1826.

Paracenoceras meridionale Tintant, 1987 Pl. 23, fig. 3; Pl. 24, figs 1, 3

1987 *Paracenoceras meridionale* Tintant: 101, fig. 21; pl. 10, figs 1, 2.

MATERIAL. Five specimens: CN70–71 from the limestone containing *Erymnoceras*, 17 m below the top of the Shuqra Formation (ie. below the base of the Lower Storm Bed at the bottom of the Madbi Formation) in central Jebel Billum; and CN68, 69 and 72 from the 'Nautiloid Bed', 6 m below the limestone with *Erymnoceras* in the same section.

DESCRIPTION. CN68 has its last septum at 185 mm diameter followed by a quarter of a whorl of poorly preserved body-chamber up to the aperture at about 230 mm diameter; at the final septum the whorl height and breadth are 105 and 140 mm respectively. CN69 is a larger isolated cast of a single air chamber between adjacent septa, and the whorl height and breadth are 138 and 178 mm. CN72 is part of a phragmocone up to 100 mm diameter. CN70 and 71, from the *Erymnoceras* bed, are isolated air chambers; the whorl height and breadth of CN70 are 61.5 and 78.0 mm, and of CN71 are 44.5 and 53.5 mm respectively. All five specimens are preserved solid, CN72 is undistorted, but the others have been subjected to varying amounts of distortion. The whorls are depressed, with whorl height/breadth ratios in the range 0.75–0.85, and the umbilicus widens considerably at larger sizes. The whorl section is trapezoidal, and the flat whorl sides converge strongly towards a venter that has a marked sulcus, which is conspicuous on whorls as small as 35 mm diameter.

MEASUREMENTS

	D	Wh	Wb	U
CN68	185.0	105.0 (0.57)	140.0 (0.76)	23.5 (0.13)
CN68	93.0	49.5 (0.53)	61.5 (0.66)	13.2 (0.14)
CN72	86.0	43.0 (0.50)	50.0 (0.58)	19.5 (0.23)

REMARKS. *P. meridionale* is a large, depressed, ventrally sulcate species, originally described from the Middle Callovian of Jebel Tuwaiq, Saudi Arabia, from two septate specimens up to 138 mm diameter. The Yemen specimens are larger, and phragmocones that are preserved up to at least 250 mm diameter indicate final diameters of 375–400 mm for complete specimens. The smaller whorls show that the ventral sulcus is present throughout growth.

OCCURRENCE. Upper part of the Shuqra Formation, central Jebel Billum; Coronatum Zone, Middle Callovian (?or Upper Callovian).

Paracenoceras* cf. *calloviense (Oppel, 1857) Pl. 24, fig. 2

1857 *Nautilus calloviense* Oppel: 547.
1873 *Nautilus calloviense* Oppel; Waagen: 18, pl. 3, fig. 2.
1927 *Paracenoceras* cf. *calloviense* (Oppel); Spath: 31, pl. 2, fig. 1, pl. 3, fig. 5.
1969 *Paracenoceras calloviense* (Oppel); Tintant: 169–181, pls 9–12.
1994 *Paracenoceras calloviense* (Oppel); Bardhan *et al*: 293, figs 3, 4, 7, 8A-C (see for more complete synonymy).

MATERIAL. One specimen, CN73, from the upper part of the Shuqra Formation, 1 km east of the Al Ma'abir road/river crossing.

DESCRIPTION. This is a wholly septate half whorl, 75 mm diameter, preserved only on one side but part of the venter is present at each end. At 75 mm diameter, the whorl height is 44.5 mm, the umbilical width is approximately 6 mm, but the whorl breadth is not seen due to the poor preservation. The whorl sides are flat and converge strongly to a flat or slightly arched venter. The suture-line has a wide, shallow lateral lobe between smaller saddles at the ventro-lateral and umbilical margins.

REMARKS. This specimen differs from the depressed, ventrally sulcate species *P. meridionale* at the same horizon in the Shuqra Formation in being more compressed and having a flat or slightly

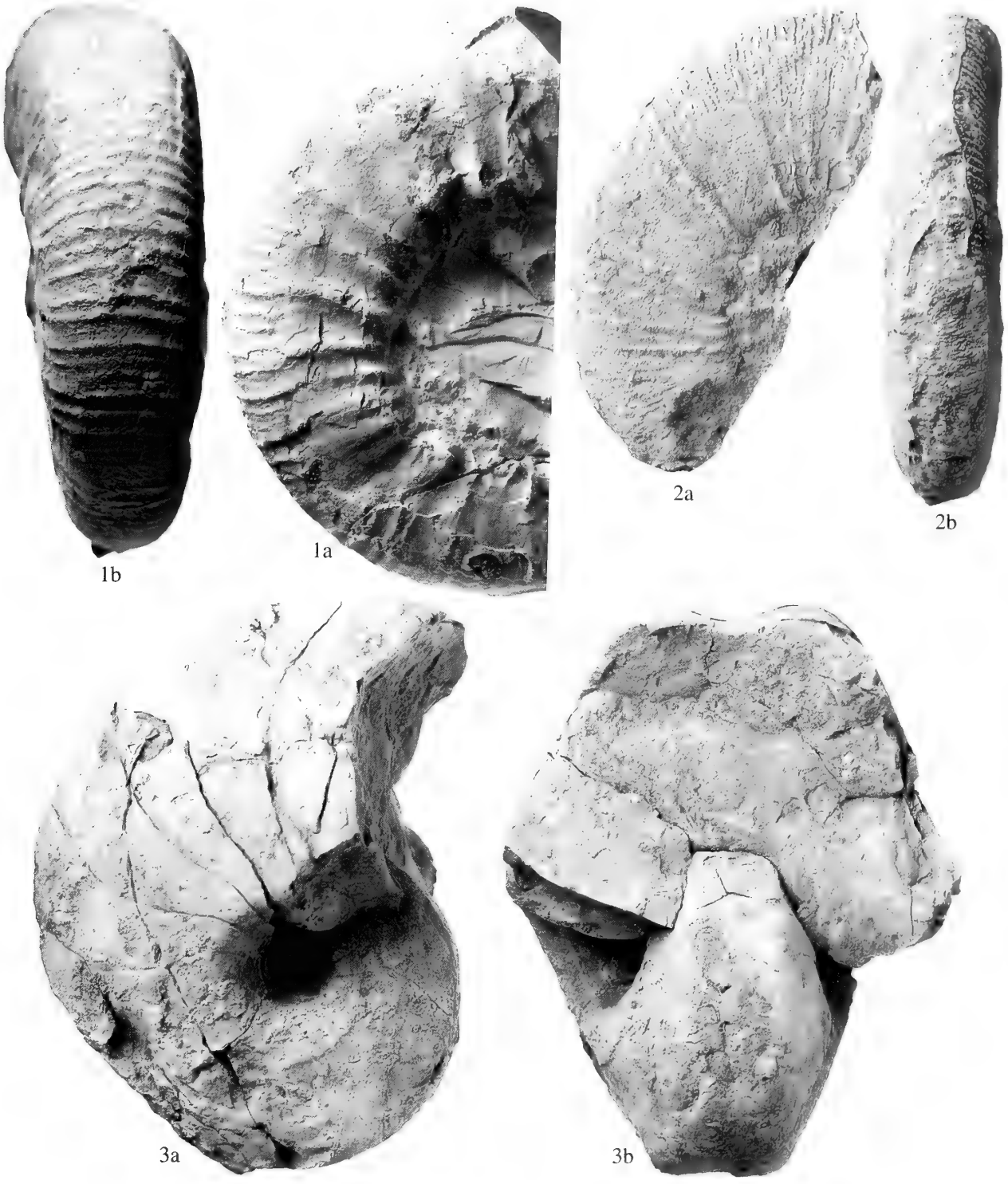

PLATE 23

Fig. 1 *Argentiniceras mutatum* (Steuer), bed 57, Mintaq Member (fauna 13), Mintaq Salt Dome. **1a, 1b,** CA693, body-chamber.

Fig. 2 *Crioceratites (C.)* cf. *villiersianus* (d'Orbigny), lower part of Qishn Formation (fauna 15), eastern Jebel Billum. **2a, 2b,** CA1298.

Fig. 3 *Paracenoceras meridionale* Tintant, 'Nautiloid Bed', 23 m below top of Shuqra Formation (fauna 1), central Jebel Billum. **3a, 3b,** CN68, ×0.57, phragmocone.

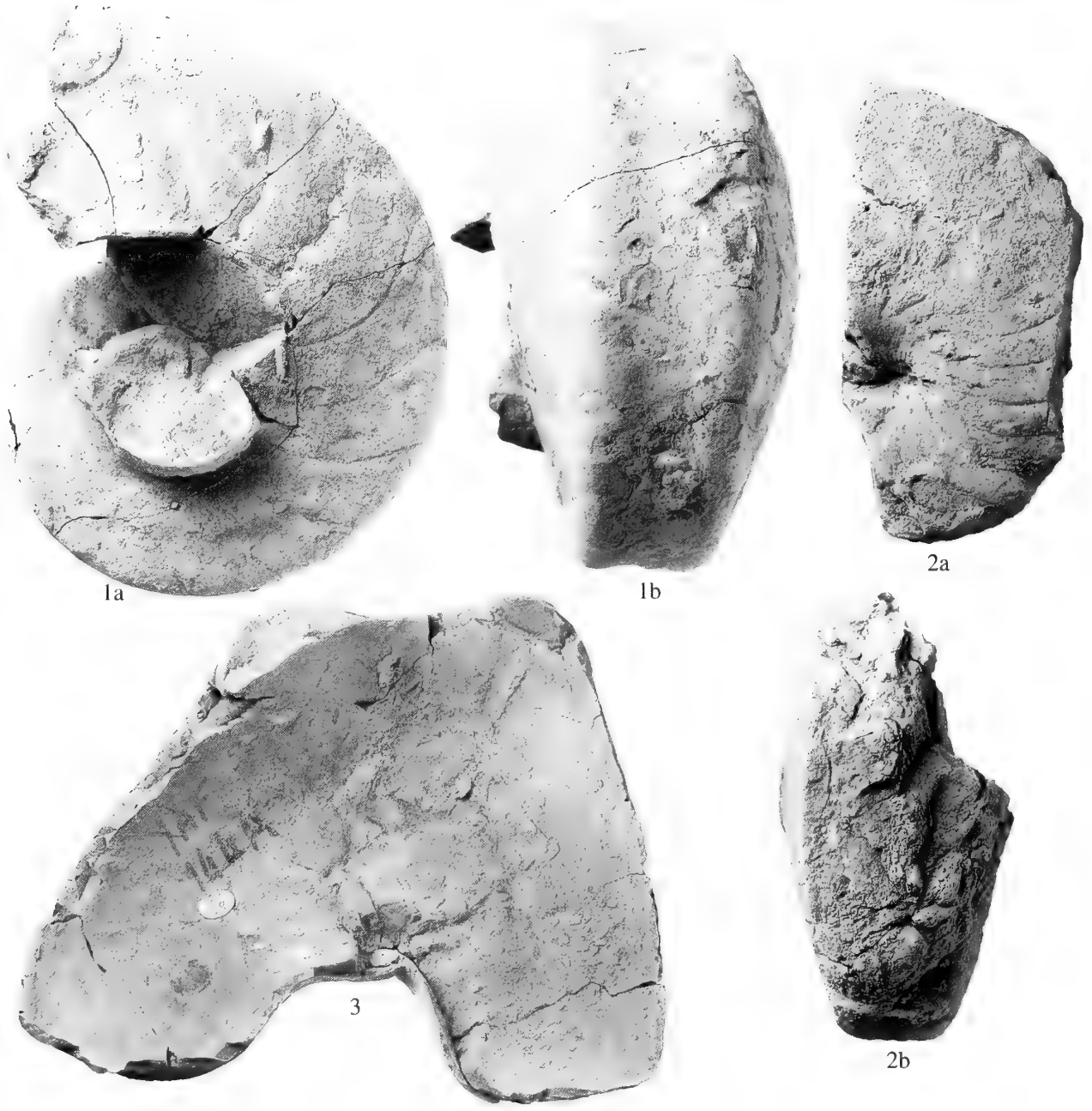

PLATE 24

Figs 1, 3 *Paracenoceras meridionale* Tintant, 'Nautiloid Bed', 23 m below top of Shuqra Formation (fauna 1), central Jebel Billum. **1a, 1b,** CN72, phragmocone. **3,** CN69, septal surface showing whorl cross-section, ×0.6.

Fig. 2 *Paracenoceras* cf. *calloviense* (Oppel), upper part of Shuqra Formation (fauna 1), 1 km east of Al Ma'abir road/river crossing. **2a, 2b,** CN73, phragmocone.

arched venter at 75 mm diameter. European examples of *P. calloviense* have been described by Tintant (1969), and large specimens (Tintant's macroconchs) do have sulcate venters, though the sulci are shallower than in *P. meridionale*. The species does not occur above the Callovian.

OCCURRENCE. Upper part of the Shuqra Formation, Al Ma'abir; Coronatum Zone, Middle Callovian (?or Upper Callovian).

Paracenoceras sp. indet.

DESCRIPTION. One specimen, CN74, from the middle limestone part of the Kilya Member, Wadi Kilya, 1 km NE of the Al Ma'abir river crossing, is a slightly distorted half whorl from a phragmocone of about 65 mm diameter. The whorls are highly depressed and have a broad, arched venter. The whorl shape and suture-line are typical of *Paracenoceras*, but the specimen is too poorly preserved for specific identification.

OCCURRENCE. Middle part of the Kilya Member, Naifa Formation, Wadi Kilya; Beckeri Zone, Upper Kimmeridgian.

BIOSTRATIGRAPHY

The ammonites described here are referred to the 14 biostratigraphical horizons ranging from the middle of the Callovian to the Berriasian that are shown as numbered asterisks in Table 1, plus the Upper Hauterivian and Upper Aptian ammonites in the Qishn Formation. The scheme of ammonite zones used here is also shown in that table, and it should be remembered that the Kimmeridgian Stage is the Kimmeridgian of the Tethyan Province, being equivalent to only the Lower Kimmeridgian of north-west Europe. The ammonites in each biostratigraphical horizon and the evidence for their dating are considered below.

Fauna 1. Middle Callovian
The discovery of three specimens of the ammonite *Erymnoceras (Pachyerymnoceras) jarryi* (Douvillé) is important for dating the Shuqra Formation. Two were found in the Upper Shuqra, 17 m below the top of the formation, in central Jebel Billum and southeast of Al Ma'abir respectively, while the third was in the top part of the Middle Shuqra at the latter locality (Howarth & Morris, 1998: fig. 6). This dates most of the upper half of the Shuqra Formation to Middle Callovian, Anceps Zone, or low Upper Callovian. A 0.5 m thick bed of limestone 23 m below the top of the Shuqra Formation in central Jebel Billum contains many large, solid, well-preserved specimens of the nautiloid *Paracenoceras meridionale* Tintant. *P. calloviense* (Oppel), indicative of the Callovian, occurs at a similar horizon in the Al Ma'abir area.

Fauna 2. Lower Oxfordian
Ammonite evidence for the age of the Madbi Formation consists of only the poorly preserved ammonites amongst the abundant brachiopods and bivalves all banked-up together in the three Storm Beds. The Lower Storm Bed is the basal bed of the formation and the only cephalopod found is a single small *Laevaptychus* from an Aspidoceratid ammonite, which does not provide much age information, though it is probably Oxfordian rather than Callovian. Two fragments of *Perisphinctes* sp. indet. and a *Peltoceratoides* sp. indet. in the Middle Storm Bed are of Lower Oxfordian age.

Fauna 3. Middle/Upper Oxfordian
Eight fragments of perisphinctids obtained from the Upper Storm Bed of the Madbi Formation are of the type of *Perisphinctes* which are characteristic of the Plicatilis, Transversarium and Bifurcatum Zones, Middle and Upper Oxfordian.

Fauna 4. Upper Oxfordian, Bimammatum Zone
Ammonites of the Bimammatum Zone occur low in the Billum Member of the Naifa Formation. The following were obtained from the basal 5 m of the Billum Member in the cliff south of the Wadi Kilya section, and 7–8 m above the base of the member at the bottom of the long eastern cliff in Jebel Billum (Howarth & Morris, 1998: figs 5, 12):

1 *Ochetoceras* sp. indet.
2 *Epimayaites* sp. indet.
3 *Paryphoceras grayi* (Spath)
5 *Larcheria gredingensis* (Wegele)
39 *Orthosphinctes polygyratus* (Reinecke)
1 *Euaspidoceras* sp. indet.

The Mayaitidae (*Epimayaites* and *Paryphoceras*) are Upper Oxfordian ammonites, while the association of *Larcheria gredingensis* and *Orthosphinctes polygyratus* is characteristic of the Bimammatum Zone. A single *Idoceras ahwarense* sp. nov. was also found loose at the base of the same Perisphinctid Cliff in eastern Jebel Billum, but it is an Upper Kimmeridgian ammonite and must have fallen from the Kilya Member.

18–20 m above the base of the Billum Member in the road cutting at the western entrance to Jebel Billum 5 *Glochiceras (G.) subclausum* (Oppel) and 1 *Orthosphinctes polygyratus* (Reinecke) were collected, which indicate the same Bimammatum Zone age.

Fauna 5. Lower Kimmeridgian, Divisum Zone
A large specimen of *Crussoliceras* cf. *wegelei* Enay found in a limestone about 8 m below the top of the Billum Member in a roadside cliff east of the Al Ma'abir road/river crossing (Howarth & Morris, 1998: fig. 3), is characteristic of the Divisum Zone, at the top of the Lower Kimmeridgian, and is the only Lower Kimmeridgian ammonite found in Wadi Hajar.

Fauna 6. Upper Kimmeridgian, Eudoxus or Beckeri Zone
The top bed of limestone of the Billum Member forms a pavement below the west side cliff in Wadi Arus, and many crushed *Streblites plicodiscus* (Waagen) and impressions of flattened perisphinctids, some of which are probably *Torquatisphinctes*, can be seen on the surface (Howarth & Morris, 1998: figs 13, 15, 16). That species of *Streblites* probably ranges from the Eudoxus to Hybonotum Zones, so its presence below a well-dated Beckeri Zone ammonite fauna shows that this top bed of the Billum member is of Eudoxus or Beckeri Zone, Upper Kimmeridgian, age.

Fauna 7. Upper Kimmeridgian, Beckeri Zone
The following very rich ammonite fauna occurs in the lower marly and middle limestone parts of the Kilya Member in Wadi Kilya, Naifa Cliff and Wadi Arus:

5 *Taramelliceras (T.) pseudoflexuosum* (Favre)
4 *Taramelliceras (T.)* cf. *intersistens* Hölder
4 *Taramelliceras (T.) compsum* (Oppel)
5 *Taramelliceras* sp. indet.
20 *Lamellaptychus*
8 *Haploceras staszycii* (Zejszner)
4 *Glochiceras (Lingulaticeras) pseudocarachteis* (Favre)
8 *Torquatisphinctes naifaensis* sp. nov.
7 *Sutneria weidmanni* Zeiss
32 *Pachysphinctes bathyplocus* (Waagen)
41 *Pachysphinctes major* Spath
5 *Pachysphinctes mahokondobeyrichi* (Dietrich)
24 *Pachysphinctes* sp. indet.
1 *Idoceras ahwarense* sp. nov.
1 *Idoceras* cf. *balderum* (Oppel)
1 *Idoceras* cf. *hararinum* Venzo
3 *Nebrodites hospes* (Neumayr)
9 *Aspidoceras longispinum* (J. de C. Sowerby)
9 *Aspidoceras apenninicum* (Zittel)
5 *Aspidoceras* sp. indet.
5 *Orthaspidoceras gortanii* (Venzo)
16 *Orthaspidoceras avellanum* (Zittel)
13 *Simaspidoceras argobbae* (Dacqué)
2 *Simaspidoceras irregulare* (Dacqué)
56 *Laevaptychus*
1 *Lithacoceras (L.)* cf. *ulmense* (Oppel)
38 *Lithacoceras (Subplanites) mombassanum* (Dacqué)

This list is a combination of the ammonites in five separate horizons in the lower marly and middle limestone parts of the Kilya Member at Naifa Cliff (see Howarth & Morris, 1998: fig. 3), five

horizons in the same parts of the Kilya Member in Wadi Kilya (Howarth & Morris, 1998: fig. 5), and from the Breadloaf Concretions in the lower marly part of the Kilya Member in the east cliff of Wadi Arus (Howarth & Morris, 1998: fig. 16). They are listed separately on those three figures, and those from the Wadi Arus Breadloaf Concretions are of especial interest. There are many indications that the whole fauna is from the Beckeri Zone and not lower in the Kimmeridgian, and the date is limited above by the Hybonotum Zone ammonites in the immediately overlying beds in Wadi Kilya. Of the 22 identified species, 12 are well-dated as occurring mainly in the Beckeri Zone in other areas in East Africa, Cutch and Europe. These include *Pachysphinctes major, Orthaspidoceras avellanum* and *Lithacoceras ulmense*, which have not been recorded below the Beckeri Zone elsewhere, and so give a lower age limit to the fauna (*Haploceras staszycii* first occurs in the top of the Eudoxus Zone, but is commoner in the Beckeri Zone). Also included is the genus *Simaspidoceras*, which is not dated accurately anywhere else in its range (Ethiopia, Somalia and Yemen) The presence of *Nebrodites* in the Beckeri Zone appears to be the highest record of this genus.

Fauna 8. Lower Tithonian, Hybonotum Zone

Lower Tithonian ammonites were obtained from the upper marly part of the Kilya Member, which occurs only in Wadi Kilya, from where the following were obtained (Howarth & Morris, 1998: fig. 5, upper marls):

9 *Taramelliceras (Metahaploceras) subsidens* (Fontannes)
32 *Katroliceras formosum* Spath
1 *Katroliceras pottingeri* (J. de C. Sowerby)
7 *Katroliceras* sp. indet.
1 *Subdichotomoceras ?latissimum* (Zwierzycki)
5 *Pachysphinctes bathyplocus* (Waagen)
5 *Pachysphinctes major* Spath
3 *Aspidoceras longispinum* (J. de C. Sowerby)
2 *Orthaspidoceras avellanum* (Zittel)
1 *Simaspidoceras argobbae* (Dacqué)
1 *Simaspidoceras irregulare* (Dacqué)
1 *Laevaptychus*
2 *Hybonoticeras ornatum* (Spath)
1 *Hybonoticeras* cf. *hybonotum* (Oppel)
1 *Lithacoceras (L.)* cf. *ulmense* (Oppel)
1 *Lithacoceras (Subplanites) mombassanum* (Dacqué)

There are many species in common with the underlying Beckeri Zone fauna, but the presence of *Hybonoticeras* cf. *hybonotum* (Oppel) and the many examples of *Katroliceras* (which is dated as Hybonotum Zone in Cutch, Kenya and Madagascar) is sufficient to show that the age is Hybonotum Zone. This is the date of the highest fauna in the Kilya Member, and the disconformity between it and the Arus Member of the Hajar Formation consists of the remainder (if any) of the Hybonotum Zone and the next four ammonite zones up to the top of the Lower Tithonian.

Fauna 9. Upper Tithonian, basal Microcanthum Zone

The lowest Microcanthum Zone fauna consists of the following ammonites obtained from the microbialite boulders from both west and east side cliffs in Wadi Arus (Howarth & Morris, 1998: fig. 16):

18 *Pseudoclambites araense* sp. nov.
2 *Baeticoceras morrisi* sp. nov.
1 *Virgatosimoceras broilii* (Schneid)
1 *Aulacosphinctes spitiensis* (Uhlig)
2 *Aulacosphinctes natricoides* (Uhlig)
1 *Micracanthoceras fraudator* (Zittel)
1 *Himalayites* sp. indet.
1 *Spiticeras gregoryi* (Spath)
1 *Virgatosphinctes* cf. *broilii* (Uhlig)
7 *Berriasella (B.)* cf. *oxycostata* Mazenot
2 *Riasanites rjasanensis* (Lahusen)
1 *Blanfordiceras wallichi* (Gray)

This is clearly an Upper Tithonian fauna because none of these ammonites occur in the Lower Tithonian, except *Virgatosphinctes* and *Virgatosimoceras*. A Microcanthum Zone date is given by the presence of *Micracanthoceras* and *Baeticoceras*, and the new species of the latter genus is morphologically the oldest species of *Baeticoceras*, indicating a basal Microcanthum Zone age for this species at least. If the microbialite boulders in Wadi Arus represent a condensed bed, then it is possible that they also contain higher horizons in the Microcanthum Zone, to which *Spiticeras gregoryi, Berriasella (B.)* cf. *oxycostata* and *Riasanites rjasanensis* could be referred. This would ease the difficulty of claiming that those species are as old as basal Microcanthum Zone.

Fauna 10. Upper Tithonian, lower Durangites Zone

An ammonite fauna that is almost completely different from that in the microbialite boulders of Wadi Arus occurs in the Arus Member in eastern Jebel Billum (Howarth & Morris, 1998: fig. 12). Of lower Durangites Zone age, it is slightly younger that the Wadi Arus fauna. The following were collected:

1 *Uhligites kraffti* (Uhlig)
3 *?Aspidoceras* sp. indet.
16 *Laevaptychus*
1 *Spiticeras* sp. indet.
22 *Virgatosphinctes* cf. *broilii* (Uhlig)
8 *Choicensisphinctes limitis* (Burckhardt)
18 *Berriasella (B.) oppeli* (Kilian)
22 *Berriasella* sp indet.
8 *Substeueroceras koeneni* (Steuer)
8 *Malbosiceras* cf. *aizyensis* Mazenot

This fauna has to be dated as Durangites Zone from the presence of *Berriasella (B.) oppeli, Substeueroceras koeneni* and *Malbosiceras* cf. *aizyensis*, none of which occur below that zone elsewhere. *Spiticeras* does not occur below the Upper Tithonian, while *Uhligites, Aspidoceras* and *Virgatosphinctes* occur throughout the Tithonian. This leaves the Lower Tithonian genus *Choicensisphinctes* as the only anomoly, for which this is the first recorded Upper Tithonian occurrence. *C. limitis* is probably the most advanced species of the genus, and persisted for longer than the earlier, less advanced species.

Fauna 11. Upper Tithonian, Durangites Zone

The base of the Mintaq Member is exposed in eastern Jebel Billum where the following ammonites were collected in the basal 6 m (Howarth & Morris, 1998: fig. 12):

2 *Uhligites kraffti* (Uhlig)
13 *Virgatosphinctes* cf. *broilii* (Uhlig)
9 *Choicensisphinctes limitis* (Burckhardt)
14 *Substeueroceras koeneni* (Steuer)
6 *Substeueroceras striatum* sp. nov.
1 *Blanfordiceras wallichi* (Gray)

Although they are only slightly different from the lower Durangites Zone ammonites 40 m below in the Arus Member in the same section in eastern Jebel Billum, from the presence of *Blanfordiceras* and two

species of *Substeueroceras*, they are probably slightly younger in age in the Durangites Zone.

Fauna 12. Upper Tithonian, upper Durangites Zone or lower Berriasian, Euxinus Zone

Few ammonites were found in the Mintaq Member in Wadi Arus, but a limestone in the upper half contains many crushed *Substeueroceras striatus* sp. nov. (27 were collected) and *Protacanthodiscus*. sp. indet. (4 were collected), and a large *Aspidoceras* sp. indet. was photographed 15 m higher in the succession (Howarth & Morris, 1998: fig. 18). Possibly similar in age is the lowest ammonite in the Mintaq succession, a single *Substeueroceras striatum* sp. nov., 25 m above the base of the Mintaq Member, and about 70 m below the main Berriasian ammonites at Mintaq. It is not possible to put a firm date to these occurrences. They could be of upper Durangites Zone age, slightly younger than the ammonites of fauna 11, or they could be of Euxinus Zone, lower Berriasian, age.

Fauna 13. Berriasian, Occitanica Zone

A rich Berriasian ammonite fauna occurs in the middle part of the Mintaq Member at Mintaq, where the following were collected (Howarth & Morris, 1998: figs 14, 20, beds 27–149):

3 *Haploceras umbilicatum* sp. nov.
2 *Aspidoceras rogoznicense* (Zejszner), with *Laevaptychus* attached
4 *Aspidoceras* cf. *taverai* Checa, with *Laevaptychus* attached
11 *Laevaptychus*
1 *Spiticeras (S.) spitiense* (Blanford)
2 *Spiticeras (S.) subspitiense* (Uhlig)
2 *Spiticeras (S.) indicum* (Uhlig)
63 *Spiticeras (S.) pricei* sp. nov.
4 *Spiticeras* sp. indet.
3 *Spiticeras (Negreliceras)* cf. *obliquenodosum* (Retowski)
1 *Spiticeras (Negreliceras) paranegreli* Djanélidzé
2 *Berriasella (B.) chomeracensis* (Toucas)
8 *Berriasella* spp. indet.
2 *Berriasella (Elenaella) sevenieri* (Le Hégarat)
1 *Substeueroceras koeneni* (Steuer)
1 *Malbosiceras* sp. indet.
1 *?Protacanthodiscus* or *Neocosmoceras* sp. indet.
1 *Neocosmoceras* sp. indet.
2 *Dalmasiceras* sp. indet.
1 *Argentiniceras mutatum* (Steuer)
5 *Argentiniceras mintaqi* sp. nov.
1 *?Neocomites* sp. indet.

From the presence of the Berriasian genus *Argentiniceras* (which has never been recorded in the Upper Tithonian) and such a rich and varied fauna of *Spiticeras*, the age is certainly Berriasian rather than Upper Tithonian, and the species of *Berriasella* indicate an Occitanica Zone age, close to or just below the middle of the Berriasian. The examples of *Aspidoceras* at Mintaq are amongst the youngest Aspidoceratidae anywhere, perhaps even the youngest of all, if the Berriasian occurrences in SE Spain are in the Euxinus Zone rather than the Occitanica Zone (see above p. 65, and Checa *et al.*, 1986).

Fauna 14. Berriasian, Occitanica Zone

Two *Tirnovella occitanica* (Pictet) collected by Dr John Smewing from near the top of the Mintaq Member on the summit of Jebel Madbi are also of Occitanica Zone, mid-Berriasian, age, though they might be slightly higher in that zone than the ammonites in the Mintaq Salt Dome section.

Fauna 15. Upper Hauterivian

A single specimen of *Crioceratites (C.)* cf. *villiersianus* (d'Orbigny) found in the basal part of the Qishn Formation in eastern Jebel Billum gives a date of Upper Hauterivian for the lower part of that formation. The unconformity between the top of the Hajar Formation and the bottom of the Qishn cuts out an unknown amount at the top of the Berriasian, the whole of the Valanginian and the Lower Hauterivian.

Fauna 16. Upper Aptian

Ammonites found higher in the Qishn Formation at Wadi Masila, 220 km ENE of Makulla, are *Cheloniceras (C.) cornuelianus* (d'Orbigny) (Pl. 21, fig. 3), *Cheloniceras (C.)* sp. indet. (Pl. 21, fig. 4) and another *?Cheloniceras* (BMNH C.71676). These indicate an Upper Aptian age at that level in the formation.

COMPARISON WITH EAST AFRICA AND INDIA

The biostratigraphical distribution of those Yemen ammonites near the Kimmeridgian-Tithonian boundary throws some light on the distribution of ammonites described from East Africa. Upper Jurassic ammonites from many areas in Ethiopia, Somalia, Kenya, Tanzania and Cutch, India, were described in an extensive British, Italian, German and French literature that was summarized up to the mid-1950s by Arkell (1956). Most of the Callovian and Oxfordian ammonites were collected from sequences that could be fairly well-dated, but many of the East African Kimmeridgian and Tithonian collections lacked good stratigraphical data, and their ages were not well determined. Included amongst the latter are most of the extensive faunas of *Pachysphinctes* and Aspidoceratids, especially those from Ethiopia and Somalia. Better information was obtained from Kenya by Verma & Westermann (1984), who were able to place *Pachysphinctes* and the accompanying Aspidoceratids in the Beckeri and Hybonotum Zones at the Kimmeridgian-Tithonian boundary from the presence of good examples of *Hybonoticeras*. In Cutch, India, *Pachysphinctes, Katroliceras* and many other ammonites were referred to the same two zones by Spath (1933: 791) and Arkell (1956: 388), a dating that has been refined more recently by Krishna & Pathak (1993), who described an evolving sequence of species of *Torquatisphinctes-Pachysphinctes-Katroliceras* in several zones across the Kimmeridgian-Tithonian boundary.

Ethiopia and Somalia remain difficult areas, however, despite the many Ethiopian ammonites described by Venzo (1959), who had little detailed stratigraphy and lumped together into a single zone all the Kimmeridgian below the Eudoxus Zone, and by Zeiss (1971), who appeared to have better stratigraphical control, but did not figure his ammonites. It also seems necessary to question the top Oxfordian to basal Kimmeridgian dates given by Scott (1943) to many of his Ethiopian ammonites, a dating that was accepted by Arkell (1956: 314, 316).

The biostratigraphical distribution of *Pachysphinctes* and *Katroliceras* in Yemen confirms that their main occurrence is in the Beckeri and Hybonotum Zones, as found by Verma & Westermann (1984) and Krishna & Pathak (1993). This is one or two zones younger than the date given by Arkell (1956: 332) to the large collection of *Pachysphinctes* and *Aspidoceras* from the Mahokondo stream in southern Tanzania described by Dietrich (1925), which may have been placed too low. The large species of *Idoceras* accompanying the Ethiopian *Pachysphinctes* described by Scott (1943) are most probably of the same age, and they are not Upper

Oxfordian *Ringsteadia* as identified by Scott. In Yemen these two zones are also the horizons at which the distinctive genus *Simaspidoceras* occurs, so its occurrence four or five zones lower in the Lower Kimmeridgian in Ethiopia (Zeiss, 1971: table 1) has to be questioned. Somalia and Yemen were much closer together during the Jurassic, before the formation of the Gulf of Aden, and the successions show much similarity (Howarth & Morris, 1998: 25). Spath's (1935) dating of the Somalian Kimmeridgian ammonites, as summarized by Arkell (1956: 309), are generally confirmed by the sequences in Yemen, though Spath had many indifferently preserved Perisphinctids of doubtful affinity. The difficulties in dating the even more poorly preserved Tithonian ammonites from Somalia described by Spath (1935) are little resolved, however, except for the 'rescue' of his poorly known genus *Pseudoclambites* by much better preserved specimens at the bottom of the Upper Tithonian in Yemen.

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CONTENTS

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